Observing: EXPLORE THE WINTER MILKY WAY p. 26

Test Report: BEST EVER $200 SCOPE? p. 60

THE ESSENTIAL GUIDE TO ASTRONOMY

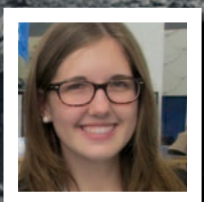
SKY & TELESCOPE

Dating Monet's Normandy Sunset p. 34

FEBRUARY 2014

Secrets of the Kuiper Belt

Revealing Pluto & Its Kin p. 18



Young Astronomer Reaches for the Stars p. 66

12 Targets for Beginning Imagers p. 70

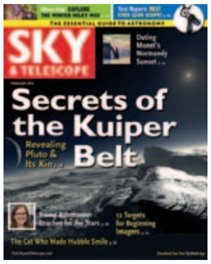
The Cat Who Made Hubble Smile p. 86

Visit SkyandTelescope.com

Download Our Free SkyWeek App

SKY & TELESCOPE

February 2014 VOL. 127, NO. 2



On the cover: This artist's impression shows the mysterious surface of Pluto, one of a large family of icy worlds.

LUÍS CALÇADA / ESO

FEATURES

OBSERVING FEBRUARY

S&T TEST REPORT

ALSO IN THIS ISSUE

SKY & TELESCOPE (ISSN 0037-6604) is published monthly by Sky & Telescope Media, LLC, 90 Sherman St., Cambridge, MA 02140-3264, USA. Phone: 800-253-0245 (customer service/subscriptions), 888-253-0230 (product orders), 617-864-7360 (all other calls). Fax: 617-864-6117. Website: SkyandTelescope.com. © 2014 Sky & Telescope Media, LLC. All rights reserved. Periodicals postage paid at Boston, Massachusetts, and at additional mailing offices. Canada Post Publications Mail sales agreement #40029823. Canadian return address: 2744 Edna St., Windsor, ON, Canada N8Y 1V2. Canadian GST Reg. #R128921855. POSTMASTER: Send address changes to *Sky & Telescope*, PO Box 420235, Palm Coast, FL 32142-0235. Printed in the USA.

February 2014 Digital Extra

BONUS WEB CONTENT

- **Vote in the Comet ISON Photo Contest!**
  Pick your favorite image between January 8 and January 22, 2014.
- **Impressionist's Art**
  View images of celestial sleuths as they track down the story behind a famous painting by Monet.
- **Stabilize Your Binos**
  Beat the binocular jiggles with this simple (and cheap!) solution.

Photo Gallery

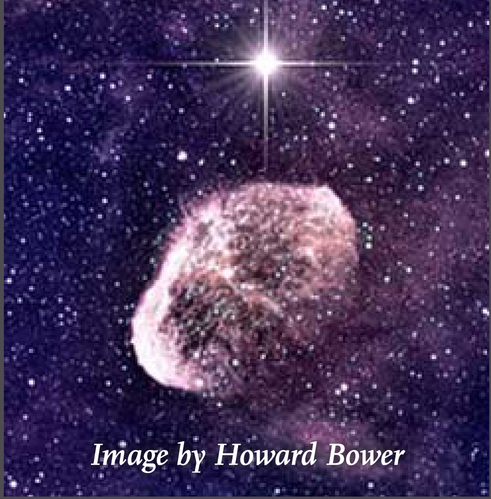


Image by Howard Bower

PBS PROGRAM
SKY WEEK

EXPLORE OUR WEBSITE

- **Online Class in Astrophotography**
  Learn the basics and the intricacies of producing beautiful astrophotos.
- **Get Involved**
  Find a club, planetarium, or observatory near you, or advertise your own.
- **Observing Guides**
  Find the resources to observe everything from planets to faraway galaxies.

FEBRUARY PODCAST AUDIO SKY TOUR

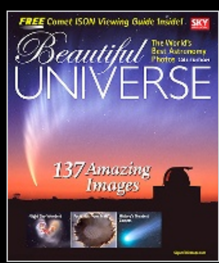
OBSERVING HIGHLIGHTS

Sign up for Newsletters, AstroAlerts, and Observing Tools

THIS WEEK'S
Sky at a Glance

DOWNLOAD OUR PLANET GUIDE APPS

Shop @ Sky



DIGITAL BACK ISSUES:
November, December, and January

Find us on Facebook & Twitter

ONLINE PHOTO GALLERY

Robert Milton captured the Milky Way behind tufa rock formations illuminated by a setting Moon. See more beautiful photos and submit your own at our online photo gallery.

Robert Naeye
Spectrum

Reflections on Comet ISON

I'M WRITING THESE WORDS on Monday, December 2nd, just hours before this issue goes to press. Unfortunately, when Comet ISON rounded the Sun, what survived perihelion quickly dispersed, leaving not enough material behind for any kind of vivid morning display in early December. Until a few days ago, my *S&T* colleagues and I held out hope that the comet might produce some kind of naked-eye display that would dazzle the world and bring new interest and exposure to astronomy. We're deeply disappointed this won't happen.

Reflecting on the past year, I realize that Comet ISON has been the most challenging story I have covered in my 22 years in astronomy journalism — with even more potential land mines than the "life on Mars" meteorite ALH 84001 in 1996. The ISON story combined the fickle, unpredictable nature of comets in general — and ISON in particular — with an extremely high public profile. From the beginning, it would have been very easy for our staff to succumb to temptation and promote the "comet of the century" hype. Fortunately, our two most experienced editors, Dennis di Cicco and Alan MacRobert, emphasized caution from the outset. They've been covering comets for more than 30 years, so they brought perspective that other media outlets and commentators often lacked.

For months, we were bombarded with conflicting information and opinions from bona-fide experts and "wannabe" experts. We followed the comet closely as it approached the Sun. For months, ISON failed to brighten according to the most optimistic forecasts, indicating that it would be an underwhelming performer. Our hopes rose when the comet started to come alive a week before perihelion. Then the news went bad, then good, then bad, then good, and then finally bad. ISON was pursuing its own agenda and not behaving like any previous comet. Despite claims to the contrary, nobody knew for certain what ISON was going to do.

This rapidly evolving story necessitated a tricky balancing act in our coverage. We didn't want to overhype ISON and contribute to a Kohoutek-like letdown. But at the same time, we wanted to convey our excitement and alert the public of the possibility of a glorious spectacle if everything worked out just right. We continually discussed our coverage strategy formally and informally. Lacking a crystal ball, we decided to convey the full range of possibilities in our printed and online communications as the comet approached the Sun. And at the critical time around perihelion, we updated our website (and Facebook page) and sent out tweets several times a day as new information and images became available.

We're deeply disappointed that ISON underperformed, but we can take solace in the fact that even in this age of an internet run amok, when those who shout loudest often attract the most attention, we did our best to stay true to our bedrock journalistic principles and deliver information with the accuracy and authority that you have come to expect from *S&T*. ✦

Robert Naeye
Editor in Chief

SKY & TELESCOPE

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

The Essential Guide to Astronomy

Editorial Correspondence: *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140-3264, USA. Phone: 617-864-7360. Fax: 617-864-6117. E-mail: editors@SkyandTelescope.com. Website: SkyandTelescope.com. Unsolicited proposals, manuscripts, photographs, and electronic images are welcome, but a stamped, self-addressed envelope must be provided to guarantee their return; see our guidelines for contributors at SkyandTelescope.com.

Advertising Information: Peter D. Hardy, Jr., 617-864-7360, ext. 2133. Fax: 617-864-6117. E-mail: peterh@SkyandTelescope.com
Web: SkyandTelescope.com/advertising

Customer Service: Magazine customer service and change-of-address notices: skyandtelescope@emailcustomerservice.com
Phone toll free U.S. and Canada: 800-253-0245.
Outside the U.S. and Canada: 386-597-4387.
Product customer service: skyprodservice@SkyandTelescope.com
Phone toll free: 888-253-0230.

Subscription Rates: U.S. and possessions: $42.95 per year (12 issues); Canada: $49.95 (including GST); all other countries: $61.95, by expedited delivery. All prices are in U.S. dollars.

Newsstand and Retail Distribution: Curtis Circulation Co., 730 River Rd., New Milford, NJ 07646-3048, USA. Phone: 201-634-7400.


Imager: Jerry Keith of Fort Worth, Texas
(Three Rivers Foundation Volunteer)
Scope: Sky-Watcher Esprit 100 EDT f/5.5
Mount: Takahashi EM200 Temma2M
Guiding: Orion SSAG Magnificent Mini AutoGuider
Camera: Canon Rebel XS (1000D) Full Spectrum
Modified @ 800 ISO
Exposure: 3.4 hours. 5 minute subs.
ESPRIT™ APO TRIPLETS
THE ELITE ASTROGRAPH FOR THE REST OF US
Designed with the discerning astrophotographer in mind, Sky-Watcher USA's top-of-the-line Esprit refractors deliver the kind of imaging performance one would expect from telescopes costing thousands of dollars more.
With their three-element air spaced objective lens design, false color is completely eliminated, yielding exceptional contrast and sharpness. The included 2-element field corrector guarantees a flat field across the entire imaging plane. The Sky-Watcher proprietary rack-and-pinion focusing system provides a smooth, rock-solid focuser with zero image shift.
Starting at only $ 1,649, the Esprits come in 80, 100, 120 and 150mm apertures and come with a 9 x 50 right angle finderscope, 2-inch Star diagonal, 2-element field flattener, camera adapter, mounting rings, dovetail plate and foam-lined hard case.
Sky-Watcher PROFESSIONAL
As this 100%-sized image from the extreme upper right corner shows, Esprit maintains crisp, pinpoint stars across the entire image plane.
©2014 Sky-Watcher USA. Specifications subject to change without notice. 20-13025.
Come on. Admit it. You know you want one. Also, a huge thanks to the folks at Three Rivers Foundation for all of their help with testing our scopes.


S&T: LEAH TISCIONE

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

Stymied by the False Dawn

Thanks for Kelly Beatty's article about the zodiacal light (September issue, page 54). It vividly brought back a memory of mine from 1986.

We'd seen the light several times, but on November 9th we wanted what we suspected would be a last look at Comet Halley through our 10-inch, f/4 handmade Dob (made by someone else). Out at 4:00 a.m. in the mountains overlooking the Anza-Borrego Desert in southern California, we had excellent viewing — we could see 13th- and 14th-magnitude stars — but no comet. I tried different lenses, then finally looked up and saw this unusually bright, large triangle of light — the zodiacal light, best we'd ever seen. It was preventing any view of Halley. But with that fabulous phenomenon, I didn't care!

John Mood
San Diego, California

Chelyabinsk's Legacy

In "Why Chelyabinsk Endures" (September issue, page 86), Christopher Cokinos writes that the videos of the Chelyabinsk impactor "remind us of our capacity to understand the universe and, specifically, to detect and deflect asteroids or, with warning, to evacuate potential impact zones." There has been a lot of recent work in this area, but unfortunately nothing is advanced enough to protect us now. The National Research Council published a comprehensive report in 2010, in which it concluded that emergency civil defense (such as evacuation) and kinetic impactors are the responses "closest to readiness." In a poster session at the International Academy of Astronautics 2013 Planetary Defense Conference in Flagstaff, Arizona, two physicists presented their DE-STAR (Directed Energy Solar Targeting of Asteroids and Exploration) concept, which would channel solar power into a laser array that would vaporize or knock off course threatening asteroids. The basic technology exists, the researchers claim, but we need to start building. And currently, the nonprofit B612 Foundation is raising funds to send an infrared telescope to a Venus-like orbit for a comprehensive near-Earth object search (*S&T*: October 2012, page 12).

Internationally the cause is somewhat stalled. In 2011 Russian Deputy Prime Minister Dmitry Rogozin proposed to the Obama administration a mutual collaboration for the strategic defense of Earth. This call for collaboration was renewed after the Chelyabinsk event but has made no headway. Perhaps publicity for these proposals could inject fresh funding into the efforts.

Julian Grajewski
Hamburg, Germany

Editor's Note: *Additional efforts include the United Nations' work to establish an International Asteroid Warning Group and NASA's Asteroid Grand Challenge, intended to spur innovation and collaboration across agencies, countries, and the public and private sectors in order to address space hazards.*

I enjoyed Cokinos's Focal Point essay, but I completely disagree with him about the lessons to be learned from the videos of the Russian meteor. While he might be correct that "impacts are the only natural disasters we can actually prevent" (and I love his low-tech solution to use white paint!), I think that the lesson of Chelyabinsk is that it came as a total surprise: despite our sophisticated technology, nobody saw it coming. Many factors were involved, not the least of which was its trajectory, which kept it close to the Sun. It struck while our attention was focused elsewhere. But isn't that always going to be the case?

Rather than reminding me of Immanuel Kant, the incident made me think of the lyrics from Tennessee Ernie Ford's tune "16 Tons":

One fist of iron,
the other of steel.
If the right one don't get you,
then the left one will.

In February, the universe did a head-fake and nailed us with a jab. We were very lucky it wasn't a knockout punch. Surely the lesson was not that we are in control, but rather the opposite.

Tom Sales
Somerset, New Jersey

Another Stellar Forty-Niner

Robert Zimmerman's account of the search for supernovae (October issue, page 16) was an entertaining and informative account of the role of amateur endeavors in this field. It highlighted the success of the two dozen or so observers coordinated by Tim Puckett, described as "the most successful by far" of amateur surveys, with a reported haul of 280 supernovae.

Although that is true, I was surprised that the world's most prolific individual searcher didn't get a mention in the article. Tom Boles uses three C14 Celestron Schmidt-Cassegrain reflectors to observe a sample of 12,000 galaxies from his private observatory in Suffolk, England. In August 2009, 12 years after his first find, Tom passed Fritz Zwicky's previous record of personal discoveries (122 supernovae), and by the end of September 2013 he'd extended his total to 154. His achievements are surely no less remarkable than the other talented amateurs mentioned in Zimmerman's article.

Ian Howarth
London, United Kingdom

Editor's Note: *Indeed we knew of Boles's achievements, but we sadly did not have space to do justice to all the amateurs* *involved in this effort. We're glad to have the opportunity here to acknowledge Boles and the many others we didn't name.*

Get in the Politics Game

Thanks for the comments offered by Robert Naeye in the October Spectrum column (page 6). As an *S&T* subscriber and amateur astronomer for the last two years, I applaud the comments regarding the loss of America's edge in science, astronomy, and space exploration.

I'm editor of the industry and government affairs section for a nationally distributed aviation magazine, where our editorial policy once concentrated on education and entertainment, not political issues. But the formal dismantling of the American manned space program caused us to change that. We felt that promotion of both aerospace and science-related activities were being forced into the background by the bitter partisan politics that seem to concentrate on political retribution, not the future of our country. Since then, we've included editorial observations and a science-related column promoting astronomy and space exploration, which, when possible, include specifics about whom to contact if readers want to extend their views to those who can make a difference. The "political pros" are dropping the ball, so maybe it is time that we amateurs help refocus elected officials on a future that extends beyond the next election cycle.

Ed Downs
Yale, Oklahoma

I agree with much of what Naeye wrote in his editorial. Of course, complaining about a "bitterly partisan Congress and a political system beholden to special interests" is a waste of time, unless you are involved in the political process. But regardless of whether Sean O'Keefe was a good NASA administrator, I recommend that readers carefully read astronaut John Young's *Forever Young*. In part, it is an indictment of the Space Shuttle: each time a mission launched, the crew was in great jeopardy. I took the opportunity to apply to the "Teacher in Space" and "Educator Astronaut" projects and had great fun applying. But had I been accepted as an astronaut candidate and found out what Young knew, I probably would have resigned. The system was built with inadequate funds to make it safe, and NASA was likely right to limit Hubble servicing missions.

I have spoken with students in my classes many times about the cost of manned missions — the whole Shuttle program cost about three to four times what Americans spent on pet food in 2012! And as Naeye noted, that money is not wasted: it pays salaries and health care and benefits for a dedicated and intelligent group of people. Even funds sent to Russia for launching astronauts help support the world economy in a positive way.

Frank Lock
Gainesville, Georgia

For the Record

✷ *The covers for the December 1963 and 1988 issues were switched in the December issue's 75, 50 & 25 Years Ago column (page 9).*

75, 50 & 25 Years Ago

Roger W. Sinnott

January-February 1939

Supernovae "It has been estimated that in any given galaxy there will appear only one [supernova] during the course of several centuries. Only about two dozen have been discovered. Most of them are in distant galaxies. . . . Such supernovae may flare up until they are as luminous as the entire galaxy in which they occur. . . .

"Light curves representing fairly long time intervals — more than a hundred days — are available for only [eight known] supernovae. . . . After the first hundred days . . . differences in speed of decline make it impossible . . . [to deduce the] maximum for the stars that have been discovered — as usually happens — long after the maximum has been reached."

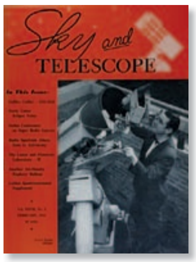
Could a remote supernova's brightness be used to gauge its distance, and hence that of its host galaxy? The prospects seemed bleak in 1939. But within a few years astronomers recognized distinct supernova types and began to compile atlases of their spectral features at successive stages of decline. Astronomers are now discovering about 1,000 per year, and Type Ia supernova observations are now calibrated to build the extragalactic distance scale.

February 1964

Landmark Conference "In mid-December an exciting international symposium on gravitational collapse as related to the problem of ultrahigh-energy radio sources was held in Dallas, Texas. The gathering [included] some 400 astronomers and relativity experts. . . .

"Many of those who attended felt that they had been at a historic occasion. . . ."

Louis C. Green (Haverford College) was reporting on what became known as the first Texas Symposium on Relativistic Astrophysics. The term "black hole" was not yet in common usage, but theoretical work already suggested that collapsed stars were inevitable. Astronomers soon realized that supermassive black holes could explain the vast energies released by quasars (September issue, page 24).



February 1989

Black Widow Pulsar "PSR 1957+20 in Sagitta has attracted the attention of observers and theorists of every stripe. After all, who wouldn't be interested in a highly magnetic neutron star spinning 622 times per second and, like a black widow spider, mercilessly destroying its companion . . . ?

"[The] system contains more than just a radio pulsar and a low-mass optical companion. Deep CCD images made in red hydrogen-alpha light at the Palomar 200-inch telescope reveal evidence of a 'pulsar wind,' . . . [which] shines where particles streaming from the neutron star smash into and shock the surrounding interstellar gas."

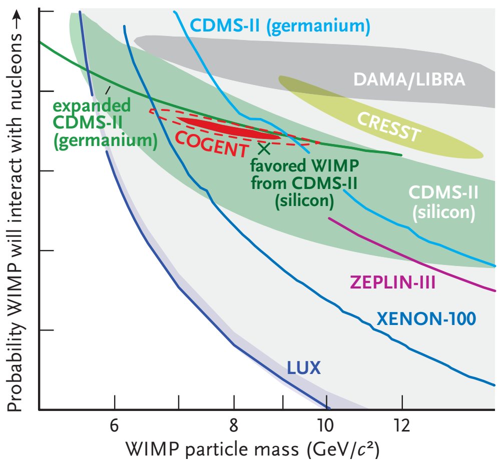
This was just the first of an exotic class of objects now known as black-widow pulsars (November issue, page 16), which eat away at their companion stars with their vicious winds.

DARK MATTER | Popular Model Takes Big Hit

Two recent experiments designed to sniff out elusive dark matter particles have come up empty-handed, calling previously promising results into doubt.

Astronomers think dark matter sculpts the largest structures in the universe, holding galaxies and galaxy clusters together. But though its existence is secure, its nature is not. The leading theory says dark matter consists of weakly interacting massive particles, or WIMPs (*S&T*: January 2013, page 26). On rare occasions, these particles should smash into other nuclei; underground detectors made of cold silicon, germanium, or xenon have the best chance of seeing the collision's signal.

Shown are results from underground experiments that seek to directly detect WIMP particles interacting with ordinary matter. Blobs mark regions where an experiment has seen signs of WIMP interactions; lines mark upper limits set by null results. The LUX experiment's upper limit (purple) rules out most previous results.



S&T: GREGG DINDERMAN; SOURCE: JEREMY CHAPMAN

Several research teams, such as CDMS-II, CRESST, and COGENT, have claimed to see hints of WIMP interactions. But these signals weren't statistically significant enough to be a sure-fire detection. And although the DAMA/LIBRA experiment has seen a much stronger signal, many physicists remain unconvinced it comes from WIMPs.

Other experiments have seen no sign of dark matter. A null result from the XENON-100 experiment cast doubt on previous detections, but physicists could massage it theoretically to evade the problem — for example, WIMPs might interact differently with silicon than with xenon.

Now the new Large Underground Xenon (LUX) experiment might have barred that way out. Richard Gaitskell (Brown University) and Dan McKinsey (Yale University) announced on October 30th the results from LUX's first three months of operations. The new detector is 20 times more sensitive than XENON-100, so if the recent CDMS-II detections were real (*S&T*: July 2013, page 16), LUX's 6-foot-tall titanium tank of liquid xenon ought to have caught some 1,600 WIMP interactions.

Instead, it saw zero.

"It does not appear possible to reconcile [CDMS-II and LUX]," Gaitskell says. Claiming that WIMPs interact differently with some elements than others won't work this time: the sensitivity is too good. "LUX's results are [also] in direct conflict with DAMA, COGENT, and CRESST."

Physicist Dan Hooper (Fermi National Accelerator Laboratory) agrees. "It would be fair to say that dark matter interpretations of the COGENT and CDMS data seem pretty unlikely to me in light of the new results from LUX," he says. "I would be lying if I said I was not more than a little disappointed."

NASA's Fermi Gamma-Ray Space Telescope is also searching for dark matter indirectly by looking for the signature of WIMP particles annihilating one another. That search has also come up empty-handed.

But neither LUX nor Fermi rule out the favored WIMP model altogether — many potential particles remain below current sensitivity thresholds.

"We will be searching for WIMPs for a while longer," Gaitskell says, undeterred. "They remain the favored quarry."

■ **MONICA YOUNG**

GALAXIES | Star Factory Found Near Cosmic Dawn

Astronomers have confirmed that light from the distant galaxy z8_GND_5296 has traveled more than 13 billion years to reach us. The galaxy is the most distant with a measured spectrum, joining the ranks of five others spectroscopically confirmed to exist in the universe's first 760 million years, or what astronomers call a redshift of 7.

A ubiquitous fog of neutral hydrogen generally hides the first stellar metropolises, but 5296's emission punches through. Even though it's fairly puny (about 1 billion solar masses, slightly less than the Small Magellanic Cloud), its brightness in different Hubble Space Telescope filters suggests that it's churning out stars at a rate a few hundred times that of our Milky Way. Astronomers expected a star-formation rate 3% as high. Paired with the high rate in a second distant galaxy, the detection indicates that star formation during this epoch might have been much higher than suspected, Steven Finkelstein (University of Texas at Austin) and colleagues report in the October 24th *Nature*.

But the team estimated that it would detect six of the 43 galaxies it set out to study, not just one. The lower return could mean that neutral hydrogen is even more abundant in this era than expected, perhaps as reservoirs within the galaxies themselves.

The results are exciting, yet it's hard to draw conclusions because there are so few data on early galaxies, says Peter Eisenhardt (JPL). "This is the frontier of knowledge, white space on our maps of the universe," he says. "Are there continents out there, or only islands, or just open sea? Anything we see is a discovery, and theory is not much guide."

■ **CAMILLE M. CARLISLE**

ORION® Since 1975

EVERYTHING FOR THE AMATEUR ASTRONOMER

ACCESSORY SALE
UP TO 30% OFF!*

Orion® Shorty™ 2x Barlow 1.25" #8711
was $46.99 NOW $39.94

Orion® Sirius™ Plössl Eyepieces, 1.25"
7.5mm #8738, 10mm #8736, 12.5mm #8726, 17mm #8734
was $47.99 NOW $33.59 each

Orion® Collimating Eyepiece #3640
was $49.99 NOW $42.49

Orion® Large Pluck-Foam Deluxe Accessory Case #5999
was $49.99 NOW $39.99

Orion® EZ Finder™ Deluxe II Reflex Sight #7231
was $79.99 NOW $69.99

Orion® Tri-Mag™ 3x Barlow Lens #8704
was $57.99 NOW $49.29

Orion® Moon Filter, 25% Transmission, 1.25" #5598
was $19.99 NOW $14.99

Orion® Waist Case™ Accessory Holder #15178
was $39.99 NOW $35.99

Orion® 9x50 Illuminated Finder with Bracket #7023
was $77.99 NOW $62.39

Orion® LRGB Astrophotography Filter Set, 1.25" #5563
was $209.99 NOW $157.49

Orion® Astrophotography Flip Mirror #5523
was $149.99 NOW $134.99

Orion® 20mm Illuminated Centering Eyepiece #8239
was $99.99 NOW $84.99

Orion® Q70™ Wide-Field Eyepieces, 2"
26mm #8827, 32mm #8828, 38mm #8829
was $99.99 NOW $79.99 each

Orion® Light Shroud for XX14 Truss Tube Dobs #15098
was $99.99 NOW $89.99

Orion® 2" Telescope Accessory Kit #8906
was $299.99 NOW $269.99

LaserMate™ Deluxe II Collimator #5691
was $69.99 NOW $59.49

Orion® Dynamo™ Pro Power Station #2308
was $139.99 NOW $119.99

Orion® RockStable™ Anti-Vibration Pads #5155
was $69.99 NOW $59.49

Orion® 9.25" ID Full Aperture Solar Filter #7722
was $139.99 NOW $118.99

* Accessory Sale Terms & Conditions

Save up to 30% off Orion accessories during our Accessory Sale! Check out our complete assortment of discounted eyepieces, Barlows, filters and more online at **OrionTelescope.com** today! Sale valid from December 27th, 2013 to January 31st, 2014, 11pm PST. Don't miss your chance to get the accessories you've been craving, with up to 30% savings!

Orders: (800) 447-1001
Customer Service: (800) 676-1343
Suggested retail prices subject to change.

OrionTelescopes.com

Shop Orion On-the-Go.
Easy Access right on your Smartphone.

Check us out on Facebook
www.facebook.com/oriontelescopes

MISSIONS | Mars Orbiters Launch

Two new Mars missions successfully launched in November, sent on their way for rendezvous with the Red Planet in September 2014.

The first, from the Indian Space Research Organization, is the ambitious Mars Orbiter Mission (MOM), informally dubbed *Mangalyaan* ("Mars Craft" in Hindi). It launched 50 years after India's first rocket and is the country's first mission beyond the Earth-Moon system.

The second, from NASA, is the Mars Atmosphere and Volatile Evolution Mission (MAVEN).

Both are orbiters that will follow highly elongated orbits around the planet, giving them both wide-angle and close-up views. MOM carries a science payload of five instruments — including spectrometers and a tri-color camera — that will work together to conduct a global survey of the Martian atmosphere and surface, particularly looking for methane and its source.

Methane has been reported in past Mars observations, but recently the Curiosity rover turned up no sign of it in the atmosphere sampled in Gale Crater (December issue, page 16). The Indian team is not dismayed: it's possible that methane's presence might vary by location, making a global survey important.

MAVEN is focused on Mars's atmosphere but will not look for methane. Various lines of evidence suggest that the planet has lost much of its ancient atmosphere and was once a warmer, wetter world. This atmosphere must have been (at least in part) lost to space, but its chemical fingerprints remain. MAVEN's team will scrutinize Mars's current atmosphere with eight instruments to determine its composition, rates of escape, and interaction with the blustery solar wind. These observations will reveal clues about what happened to the ancient (and potentially habitable) Martian climate.

■ **CAMILLE M. CARLISLE & SHWETA KRISHNAN**

CHELYABINSK | Sobering Results

The mega-meteor that exploded over Russia last February 15th (*S&T*: June 2013, page 24) has been a bonanza for impact specialists thanks to the wealth and diversity of observations. In early November they announced their initial findings in two articles published in *Nature* and a third in *Science*.

The object itself, about 19 meters (62 feet) across with a mass of roughly 12,000 metric tons (nearly twice the initial estimate), came in on a highly elongated, low-inclination orbit that's a close match to that of the unnamed asteroid 86039.

Recovered fragments reveal that the incoming object was a single cohesive body — but only barely so, according to Olga Popova (Institute for Dynamics of Geospheres, Russian Academy of Sciences) and colleagues. The stony interiors are crisscrossed by a network of fractures filled with metal-rich glass. These preexisting fractures weakened the rock's structure, and it broke apart along those veins.

More sobering is an analysis by Peter Brown (University of Western Ontario, Canada) and others, which used atmospheric impact records (instead of just near-Earth-object discovery statistics) to estimate the frequency of these hits. They conclude that blasts of this magnitude might not be a once-per-century event, as had been thought, but instead might come on average every few decades.

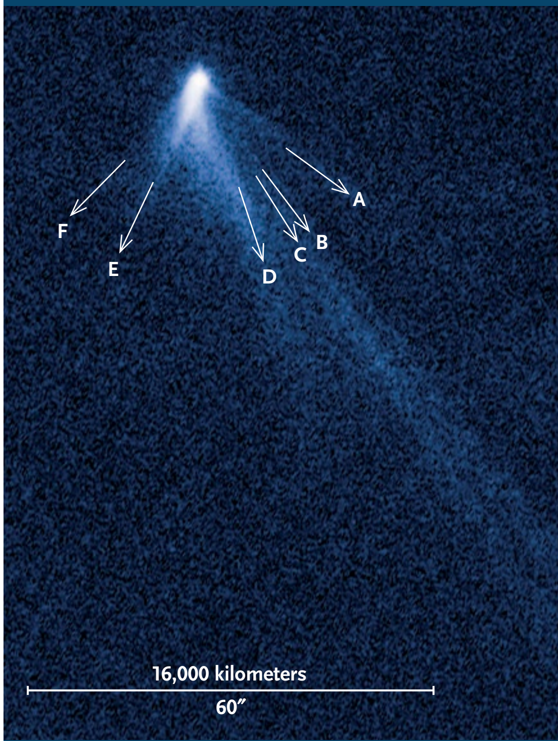
Another concern is that most researchers thought that objects in this mass range would disintegrate higher in the atmosphere. Now the thinking is that these blasts are driven deeper down by their own momentum, an idea first put forward six years ago by Mark Boslough and David Crawford (Sandia National Laboratories) to explain the roughly 2,000 square kilometers of devastation caused by the Tunguska impact in 1908.

■ **J. KELLY BEATTY**

ASTEROIDS
Rock Sprouts Tails

First thought to be a comet lurking among the asteroids, the object P/2013 P5 turns out to be a rock shedding tails of dust into space. Two sets of Hubble images taken by David Jewitt (University of California, Los Angeles) and colleagues reveal six tails that changed dramatically between when this image was taken on September 10, 2013 and two weeks later. Each tail appears to have been shed by the central body on a specific date. The tails' shapes suggest their tiny particles range from 10 to 100 microns in size. As the team conjectures in November 20th's *Astrophysical Journal Letters*, if the central mass is spinning rapidly (which is plausible), then dust on its surface might be sliding toward its equator, where it piles up and sloughs off into space, creating the tails. Since the tails together represent no more than about 0.1% of the body's mass, they'll likely keep appearing until the near-surface dust runs out.

■ **J. KELLY BEATTY**



NASA / ESA / DAVID JEWITT (UCLA) ET AL.

TelescopeS.NET
by Woodland Hills Camera & Telescopes
MEADE
LX850
Built-in guiding for imaging
CELESTRON
CGE Pro 1400 HD
Your ultimate portable 14" scope
PlaneWave INSTRUMENTS
Why wait for your favorite CDK when you can have one now?
EXPLORE SCIENTIFIC
100 degree eyepieces for as little as $249
TAKAHASHI
An amazing wide field refractor
AIS Apogee IMAGING SYSTEMS
The Aspen by Apogee The 16803 chip that never quits
OFFICINASTELLARE
Veloce RH 200
8" f/3.0 astrograph
SBIG ASTRONOMICAL INSTRUMENTS
STi
The must have guider from $595
Shelyak INSTRUMENTS
Exciting and affordable spectrograph from Shelyak $759
SKYRIS
Afordable new 120 FPS, USB3 imager from Celestron
CORONADO
Rich View SolarMax II
An amazing H alph as little as $1299
LUNT SOLAR SYSTEMS
LS35TH Dedicated H-Alpha Solar Telescope
Basic $598
Deluxe (shown) $673
Paramount MX Engineered for productivity
SOFTWARE BISQUE
FLI Finger Lakes Instrumentation
Atlas Digital Focuser High payload precision focuser
TeleVue Visionary
Tele Vue NP127 IS, Incredibly sharp, astrophotography ready
Canon
EOS 60Da DSLR Astrophotography Camera
Last call while supplies last!
Incredible StarLapse System Performance and versatility $695.00
LOSMANDY
Vixen Optics
Sphinx SXD w/tripod Rock solid, unparalleled controller $1,995.00
ATIK CAMERAS
Titan CCD Camera Planetary and deep-sky imager $689
888-427-8766 Intnl: 818-347-2270 • 5348 Topanga Canyon Boulevard, Woodland Hills, CA 91364

IN BRIEF

Charred Earth Hugs Star. At 1.2 Earth radii and just under 2 Earth masses, Kepler-78b is now the smallest exoplanet with a known density, two independent teams report in the November 21st *Nature*. Its density matches Earth's. But the planet skims less than two stellar radii above its host star's visible surface, heating it to three times Mercury's dayside temperature and qualifying it (if it were a comet) as a sungrazer. Kepler-78 is also young and awash with starspots, meaning the world is a prime target for coronal ejections. The planet probably migrated to its current position from farther out.
■ CAMILLE M. CARLISLE

Planetary System Out of Whack. The red giant star Kepler-56 spins on an axis bizarrely offset by 45° from its two transiting planets, report Daniel Huber (NASA Ames Research Center) and colleagues in the October 18th *Science*. The team used tiny brightness changes from starquakes to find the star's poles and equator. Follow-up at Keck Observatory revealed a gravitational wobble caused by a third, massive companion on a wide orbit that's at least 10 times farther out than Kepler-56b and c. The third companion (whether it's a gas giant or star) might have shifted the inner planets' orbits over time, explaining the tilt.
■ MONICA YOUNG

Bite-size System. The crowdsourcing citizen-science program Planet Hunters has identified 14 new exoplanet candidates in Kepler's data that the Kepler team missed. Of those, eight lie in their stars' habitable zones and two are in multiplanet systems. Most significant of the discoveries is the Neptune-size KOI-351.07, a seventh planet in a system already known to have six — making that system the first discovered with seven planets, at least two of which are probably rocky. The host star is slightly hotter and larger than our Sun, but the system itself is a bite-size doppelgänger of our own: all seven planets orbit within one Earth-Sun distance of the star.
■ EMILY POORE

EXOPLANETS | Kepler Hits 3,500 Candidates

Kepler can now officially boast finding more than 3,500 exoplanet candidates. The announcement came November 4th, when the team released its analysis of data from the first three years of observation, combining the third year with data from years one and two (previously released).

The new analysis adds 838 candidates to the existing Kepler catalog and focuses on smaller planets. The enlarged Kepler haul suggests about 70% of stars are host to at least one planet, confirming that planets are a common cosmic occurrence. There are now 1,750 candidates that are super-Earth-size or smaller, and 1,788 at Neptune-size or larger. Only 167 of the 3,538 candidates are *confirmed* to be planets, but Kepler has a good track record: the vast majority of these are probably real.

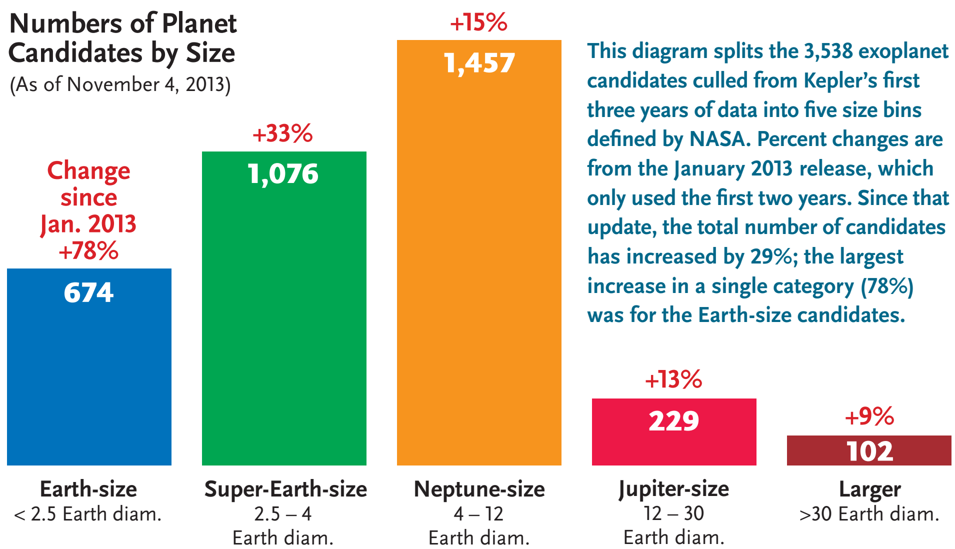
Two dozen of the new candidates orbit in their parent star's habitable zone — defined for simplicity's sake as the region in space with the right amount of starlight to create life-friendly temperatures on an Earth-like planet. Of those, 10 are about double Earth's size or smaller and are thus possibly rocky in composition.

With these additions, there are now a total of 674 Earth-size candidates, a 78% increase compared with the team's January 2013 release that was based on the mission's first two years of observations (*S&T*: April 2013, page 12). Given the larger data set, researchers estimate that one in five Sun-like stars hosts at least one rocky planet orbiting in its habitable zone. That ratio is about the same as what astronomers have calculated for the prevalence of rocky planets in orbits smaller than Mercury's, as well as the prevalence of rocky planets around cool, small *M* dwarfs.

The increase in Earth-size candidates over other planet sizes is due not only to having more observations in hand, but also to refinements in researchers' vetting and analysis — in other words, researchers are getting better at detecting Earth-size planets. The team postulates that the final, fourth year of data (which is still unexplored) will be the most important in the search for small exoplanets.

Kepler ended its fruitful planet hunt in May 2013 (*S&T*: August 2013, page 10), but the team is proposing a new mission called K2 that would continue the exoplanet hunt despite the spacecraft's failed flywheels. Since the problem is one of precision and stabilization, the plan is to point the telescope along the ecliptic plane. In this position, the pressure from solar radiation will act as a virtual third wheel, balancing out the two still-working wheels to enable a pointing precision that (the team hopes) will be on par with what Kepler had in its full-functioning state. K2 would search for planets around smaller, cooler dwarf stars and in a range of stellar environments not in Kepler's previous view, such as star clusters and nurseries. ✦

■ EMILY POORE



This diagram splits the 3,538 exoplanet candidates culled from Kepler's first three years of data into five size bins defined by NASA. Percent changes are from the January 2013 release, which only used the first two years. Since that update, the total number of candidates has increased by 29%; the largest increase in a single category (78%) was for the Earth-size candidates.

S&T: GREGG DINDERMAN; SOURCE: NASA

So Many Worlds, But Is Anybody Home?

Kepler's findings of Earth-like worlds furthers the motivation for SETI.

THE NEW REVELATION from Kepler is satisfying: 1 in 5 Sunlike stars in our galaxy has at least one Earth-sized planet orbiting in its habitable zone (page 14). But this result is not particularly surprising if you've been following the mission. As expected, Kepler's first harvest of planets turned up non-Earths, since it's much easier to detect star-broiled giants on tiny orbits. But as the larger demographic pattern started to emerge, it became clear that there must be a lot of Earth-size worlds out there unless, for some strange reason, planet formation discriminates against worlds like our own.

So this news is a confirmation. We scientists like to avoid basing too many of our views on inductive logic or extrapolation. It seemed as though potentially habitable planets should be there, but it feels comforting to place them firmly in the "directly supported by empirical evidence" column. Now that we know there are many potential Earths in our galaxy — two or three for each person alive — what are the implications for SETI?

One of the great unknowns has been the number of life-friendly planets. We're finally nailing this down, and it looks marginally consistent with the dreams of the wild optimists who see a universe teeming with life. When the "Order of the Dolphin," consisting of Carl Sagan, Frank Drake, and a handful of other thinkers, first tried to quantify the number of galactic civilizations, in 1961, they guessed that 20 to 50 percent of stars have planets and that each system has between 1 and 5 habitable planets. This leads to a predicted number of 0.2 to 2.5 habitable planets per star. So the real galaxy turns out to be just barely within their estimated range.

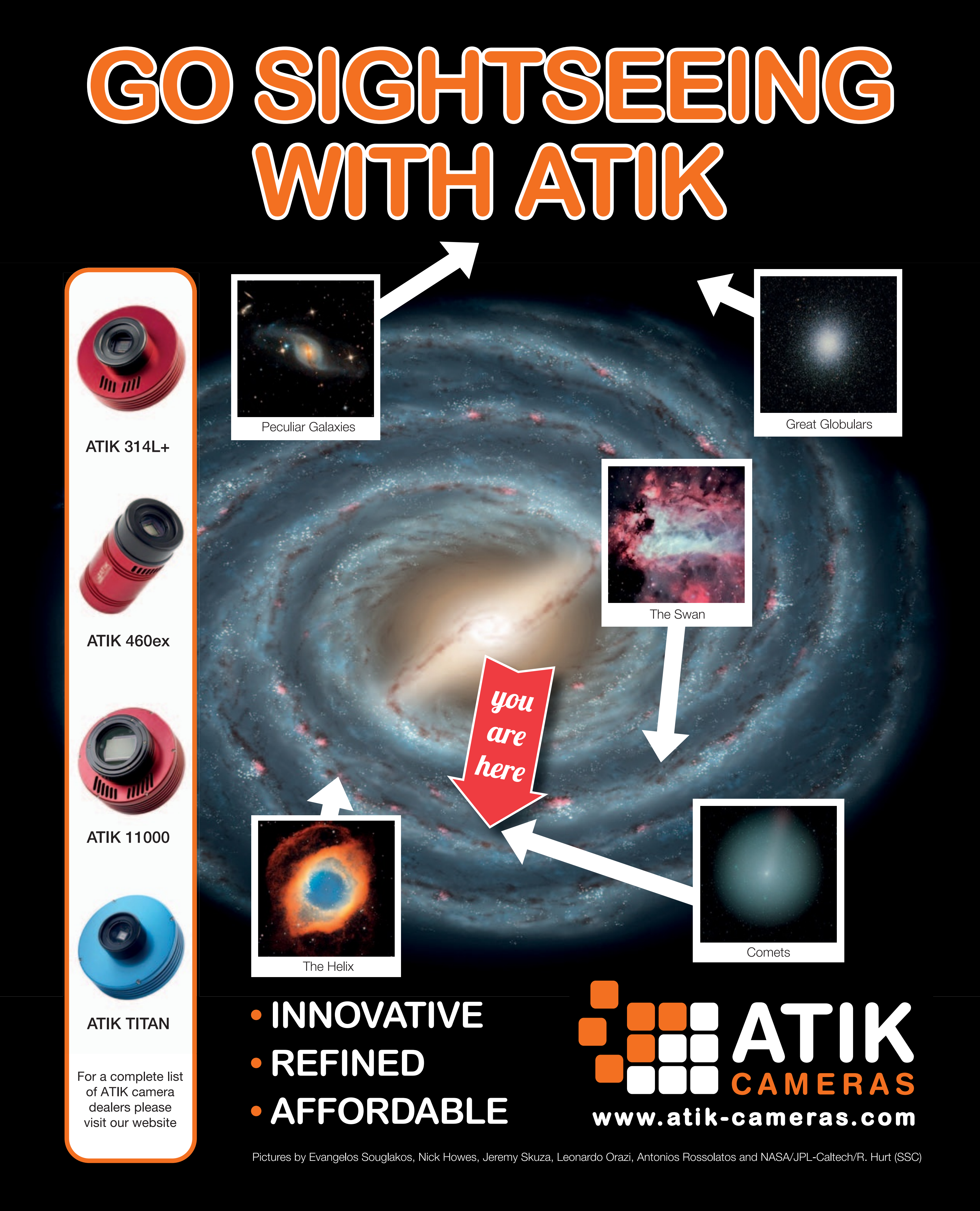
The Dolphins predicted that 100% of habitable planets will develop life, and we can test this on Mars and Venus by seeing if anything got started back when they had oceans. They also predicted that 100% of planetary biospheres develop intelligence. Perhaps we can test this among the exoplanets.

These worlds suggest a new way to search that does not depend on the assumption that alien technologists will build radio telescopes to amuse creatures such as us. A safer assumption is that aliens will purposefully alter their worlds. Why? Because a long-lived civilization on an Earthlike planet will be like the city of New Orleans, requiring engineering to maintain habitability against natural changes. If we're not alone, we should find such artificially enhanced planets out among the exos.

So Kepler's significance for SETI is threefold. First, it has nailed down the physical factors well enough, and the news is good. Second, we have the means to study the biological and social factors by looking for living and artificially enhanced worlds. And third, Kepler's findings will help provide the societal impetus to find these answers. We know how to discover what's in the air around these worlds. Building a giant space telescope that can tell us — a terrestrial planet finder — requires merely the will to do it. The exciting knowledge that we live in a galaxy full up with potential Earths will excite a mass hunger to know. ✦

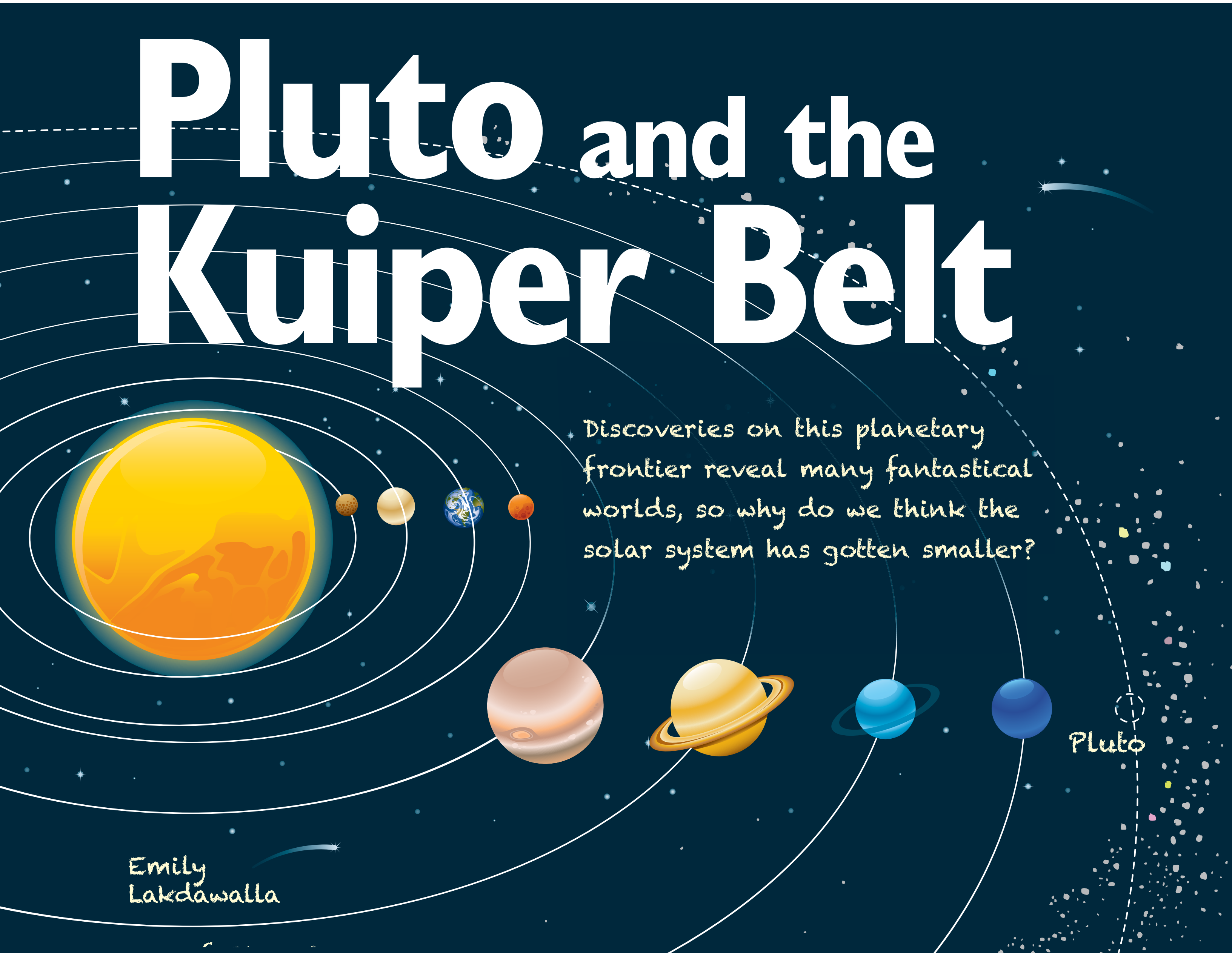
NASA AMES / JPL-CALTECH / TIM PYLE

David Grinspoon *is Baruch S. Blumberg Chair of Astrobiology at the Library of Congress. Follow him on Twitter at @DrFunkySpoon.*


GO SIGHTSEEING WITH ATIK
ATIK 314L+
ATIK 460ex
ATIK 11000
ATIK TITAN
For a complete list of ATIK camera dealers please visit our website
Peculiar Galaxies
Great Globulars
The Swan
you are here
The Helix
Comets
• INNOVATIVE
• REFINED
• AFFORDABLE
ATIK CAMERAS
www.atik-cameras.com
Pictures by Evangelos Souglakos, Nick Howes, Jeremy Skuza, Leonardo Orazi, Antonios Rossolatos and NASA/JPL-Caltech/R. Hurt (SSC)

Pluto and the Kuiper Belt

Discoveries on this planetary frontier reveal many fantastical worlds, so why do we think the solar system has gotten smaller?



Emily Lakdawalla

©ISTOCKPHOTOS.COM / APPLEUZR

MY DAUGHTER was born three weeks before the International Astronomical Union held its fateful vote on the definition of the word "planet" (*S&T*: November 2006, page 34). As far as she has ever known, Pluto is not a planet. Her teachers also know that Pluto isn't a planet. But if it's not a planet, then what is it? Asked this question, every one of them has told her that Pluto is actually some kind of star!

While I find this statement astonishing, I can't blame teachers for not understanding what Pluto actually is. Being a space enthusiast, I'm well aware that its status has changed because of recent discoveries of more than 1,000 other bodies in Pluto's neighborhood, transforming our understanding of the shape of our solar system. However, as a parent, I've seen that Pluto's redefinition to "dwarf planet" has resulted in its swift redaction from children's books, games, and toys. The redefinition happened because we learned more about the solar system, but the change in status has resulted in us teaching our children (and, perhaps more importantly, their teachers) *less*.

As an educator, I wanted to correct the "some kind of star" error, but here I was halted by my own ignorance. I could name a few Kuiper Belt objects (KBOs), and I knew the solar system looked different from the orderly progression of nine worlds that my childhood books presented, but I didn't have a new mental picture of the solar system to go by. Where do all the newly discovered objects fit? Is the Kuiper Belt just a second, icier asteroid belt, or is it something different? Do we know Pluto's large neighbors as distinct worlds yet? What's going on out there beyond Neptune, anyway?

I've done some homework and have had lengthy conversations with several prominent astronomers, and I can now paint you (and me) a picture of the new solar system. Here's a spoiler: the Kuiper Belt is *not* just a second asteroid belt. Its present shape holds important clues to the puzzle of how the solar system formed. And if you're among those who think Pluto should still be called a planet, then I'll show you that there are at least a hundred other planets out there beyond the eight we now name.

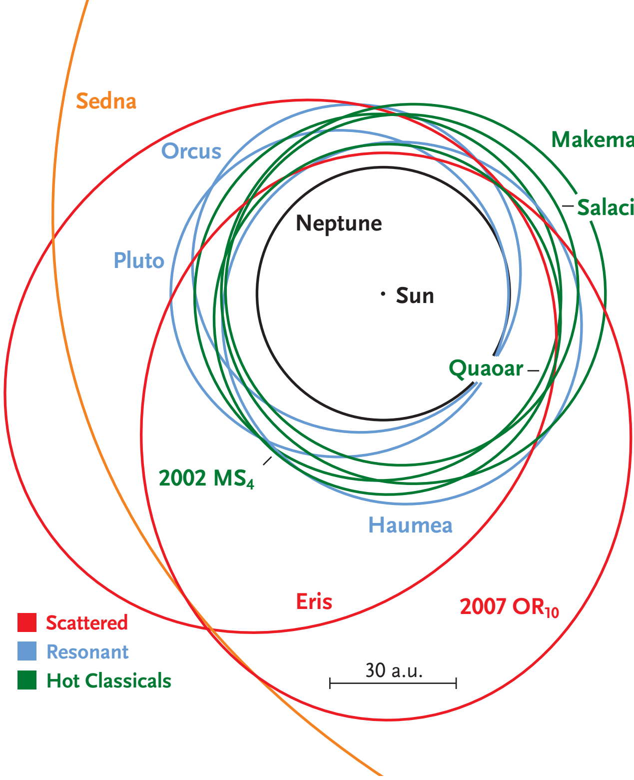
They're Everywhere

Studying the Kuiper Belt strains the capabilities of every observational method because the objects are so faint and so cold. At first, all astronomers could do was detect them and calculate their orbits. Pluto's orbit is typical of one large class of KBOs. It's quite elongated, inclined to the ecliptic plane that contains the orbits of the eight planets, and in a 2:3 orbital resonance with Neptune, going around the Sun twice every three Neptune years.

With the advent of CCD astronomy in the late 1980s, David Jewitt (now at University of California, Los Angeles) and Jane Luu (now at MIT Lincoln Lab) were able to perform the first modern survey of the sky for Pluto neighbors. They discovered the first in 1992. More discoveries followed every year. By the time that a few dozen trans-Neptunian objects had been found it was abundantly clear that Neptune ruled this region of the solar system: many of the icy worlds shared Pluto's 2:3 orbital resonance with Neptune, and even more were in the wider-ranging 1:2 resonance. Nearly all of the others orbited in between these two resonances, with semimajor axes filling in the space between 38 and 48 astronomical units.

As astronomers discovered more and more objects, other patterns and groupings emerged. There are some objects beyond the 48-a.u. cutoff. But even they are ruled by Neptune. All of them, save one, are on elongated orbits that eventually take them back to this dense part of the belt. No matter how far away they go, these "scattered" objects always come back.

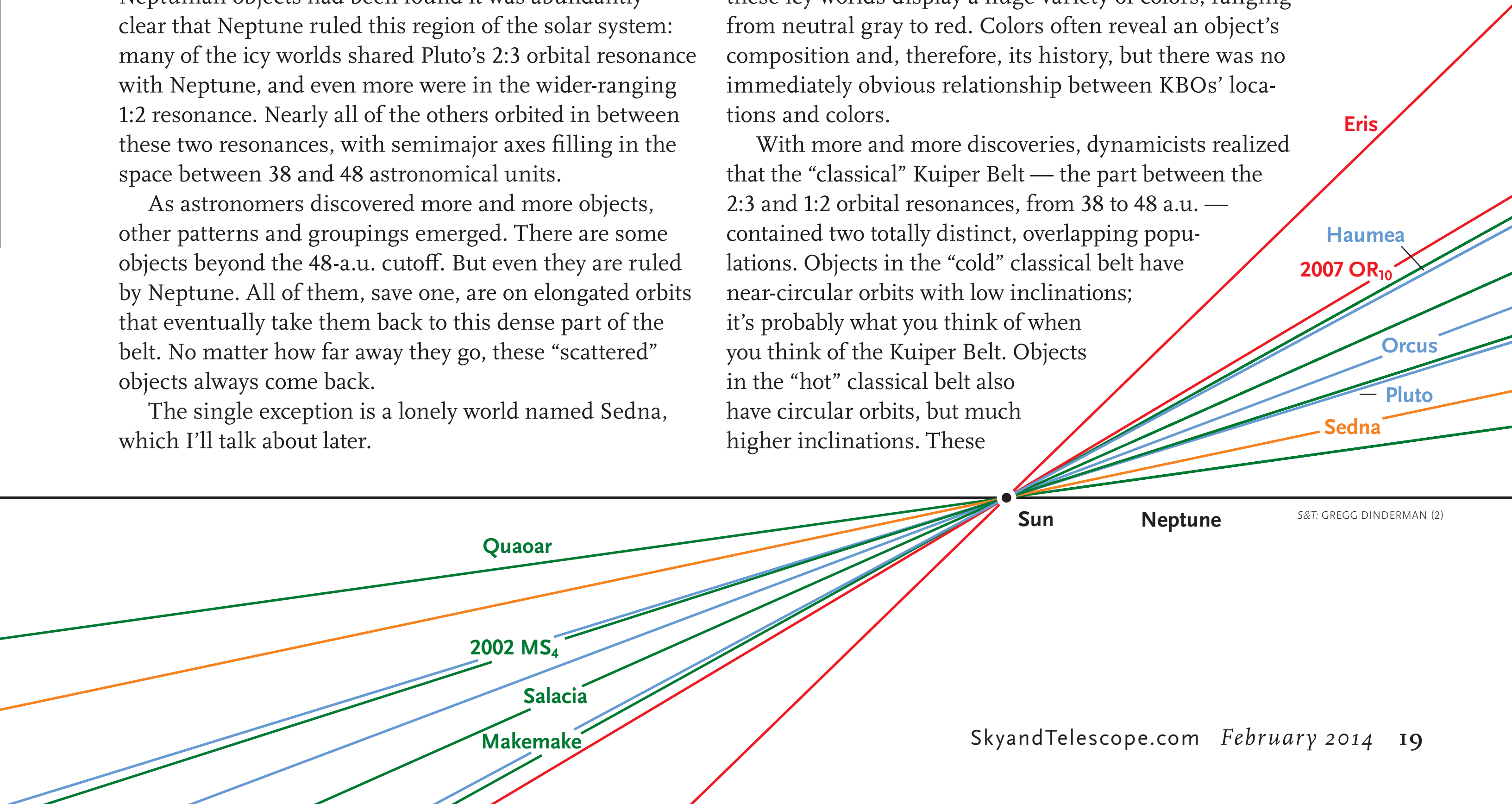
The single exception is a lonely world named Sedna, which I'll talk about later.



NOT REALLY A BELT. Kuiper Belt objects fall into distinct populations (Sedna is an oddball), distinguished by their orbits and surface hues. Shown above are orbits for the largest worlds as if the bodies traveled in the same plane as Earth does; below, the orbits' inclinations appear relative to Neptune's, which at this scale matches those of the other classical planets. Not shown are the "cold classicals": their orbits are shaped like the "hot" ones but have low inclinations.

As astronomers began to follow up discoveries with more detailed examinations of the objects' colors, they found another surprise: unlike in the asteroid belt, these icy worlds display a huge variety of colors, ranging from neutral gray to red. Colors often reveal an object's composition and, therefore, its history, but there was no immediately obvious relationship between KBOs' locations and colors.

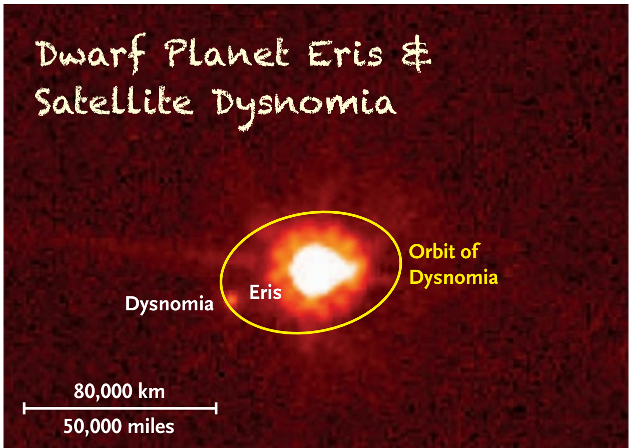
With more and more discoveries, dynamicists realized that the "classical" Kuiper Belt — the part between the 2:3 and 1:2 orbital resonances, from 38 to 48 a.u. — contained two totally distinct, overlapping populations. Objects in the "cold" classical belt have near-circular orbits with low inclinations; it's probably what you think of when you think of the Kuiper Belt. Objects in the "hot" classical belt also have circular orbits, but much higher inclinations. These



S&T: GREGG DINDERMAN (2)

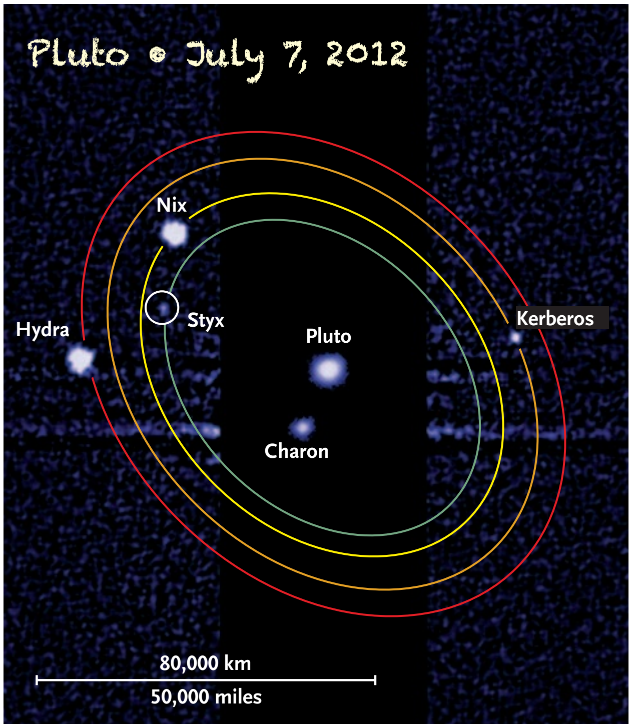
classifications aren't just astronomical hair-splitting: these are two populations that have distinctly different colors. The hot objects must have a different history from the cold objects — yet they're orbiting in the same region of space.

What did all of this mean? A major clue came from outside the solar system entirely. At the same time as the Kuiper Belt was first being surveyed, astronomers had also begun to discover planets around nearby stars. Many of these exoplanets were so-called "hot Jupiters," giant worlds on insanely tight orbits around their stars. Given what (little) we know about planet formation, these boiling-hot gas planets couldn't possibly have formed in their present locations. But that meant that, against conventional wisdom, these gigantic worlds must somehow have formed very far from their stars, then migrated inward.



DISTANT MYSTERY. This Hubble Space Telescope image from 2011 shows the dwarf planet Eris and its moon, Dysnomia. Eris and Pluto are the same size, but Dysnomia is only about one-tenth the size of Charon (see page 23).

NASA / ESA / MICHAEL BROWN (CALTECH)



PLUTO AND ITS KIDS. This composite of three sets of 3-minute-long exposures taken on July 7, 2012 with Hubble's Wide Field Camera 3 reveal all five of Pluto's known moons. Pluto and Charon's brightness are reduced, and the faint horizontal stripes are imaging artifacts.

NASA / ESA / MARK SHOWALTER (SETI INSTITUTE)

If exo-Jupiters can move inward, researchers reasoned, then perhaps the giant planets in our own solar system are not in their original locations. They saw that if Neptune had migrated *outward* since it formed and intruded into a primordial belt of cometlike objects, it would have eaten a few of them and scattered the rest like billiard balls, trapping some in orbital resonances and sending others inward toward the Sun.

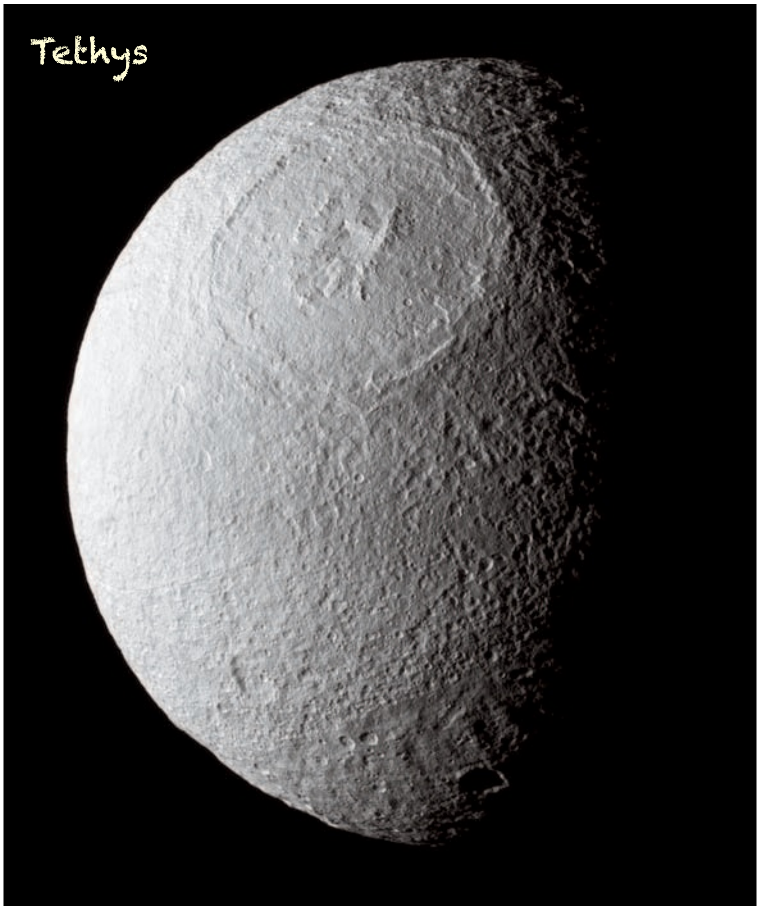
A few of the inward-moving objects stayed safely in the outer solar system as Trojans. But the majority of these travelers would have kept right on going. The resulting cascade of comets into the inner solar system could have contributed to the Late Heavy Bombardment, thought to have pelted the inner planets and moons a few hundred million years after the solar system formed (*S&T*: August 2011, page 20).

The present distribution of orbits in the Kuiper Belt is thus a crime scene, preserving evidence for the havoc wreaked when Neptune invaded its domain. Dynamicists still don't know exactly how Neptune perpetrated the crime, though — it's hard to write a history of Neptune's motion that can create the various "excited" populations in the Kuiper Belt (the resonant, scattered, and hot classical objects) while leaving the cold classical disk unscathed.

In the early 2000s, Mike Brown (Caltech), Chad Trujillo (Gemini North Observatory), and David Rabinowitz (Yale) began new CCD-assisted surveys specifically designed to detect large trans-Neptunian objects, resulting in the discoveries of several of the largest now known. The KBO discovery rate peaked in 2003, with nearly 200 discovered that year; in 2011, fewer than 20 were found. The discovery rate has dropped not just because we've found all the bright ones, but because the rarefied group of astronomers working on this distant part of the solar system has largely moved on from describing them as a population to studying them as individuals.

Size Matters

To discover the Kuiper Belt, astronomers used intermediate-size, wide-field telescopes. But to characterize its inhabitants, astronomers have moved to the biggest and smallest telescopes. Some are using the Hubble Space Telescope, the Very Large Telescope in Chile, and Keck on Mauna Kea to study the objects' colors and compositions in visible and near-infrared wavelengths. They are finding the population to be remarkably diverse in hue and



NASA / JPL / SPACE SCIENCE INSTITUTE (2)

A SORTING GAME. Kuiper Belt objects smaller than 400 km across probably resemble Saturn's moon Phoebe, a beat-up, icy body with similar surface chemistry. Those larger than 400 km might look more like Tethys, shown here with its 450-km-wide Odysseus Crater prominently displayed. These larger bodies are rounded by self-gravity and perhaps smoothed by icy outflows.

covered with a wide variety of ices taking an equally wide variety of forms.

Other astronomers use observations from the great space-based infrared telescopes, including Spitzer and Herschel, to measure KBOs' temperatures and sizes. The thermal infrared brightness, coupled with the visual magnitude, provides a tight constraint on the diameters and albedos of these worlds. This work has told us that KBOs are remarkably diverse in reflectivity, ranging from the bright white of new-fallen snow to pitch black.

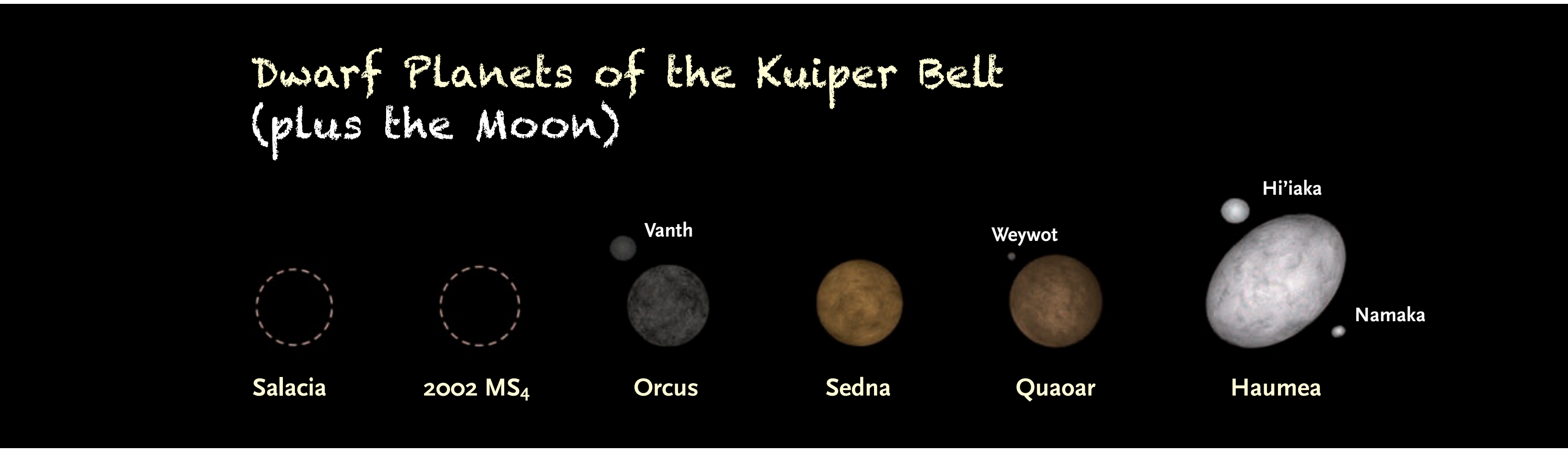
A few astronomers (including both professionals and amateurs) instead marshal as many telescopes as they can, of all sizes and all over the world, to watch as the distant, faint objects occult even more distant (but much brighter) stars. These stellar occultations give us the most precise diameter measurements, and they have also enabled us to probe Pluto's atmosphere, an atmosphere that, ironically, prevents us from precisely measuring the world's diameter from afar.

Astronomers aren't measuring diameters just to rank the objects by size. For the objects that have satellites (estimated to be as many as 30% of them), the orbital speed of those satellites tells us the objects' masses. Together, mass and diameter reveal density. The KBOs' densities, too, are all over the map, telling us that some are made of nearly pure ice, whereas others are mostly rock with only a thin ice veneer.

Of course there is a spacecraft headed to the Kuiper Belt: NASA's New Horizons mission, which will fly past Pluto in July 2015 and give us our first close encounter with this new region of the solar system (*S&T*: June 2010, page 30).

Family Portrait

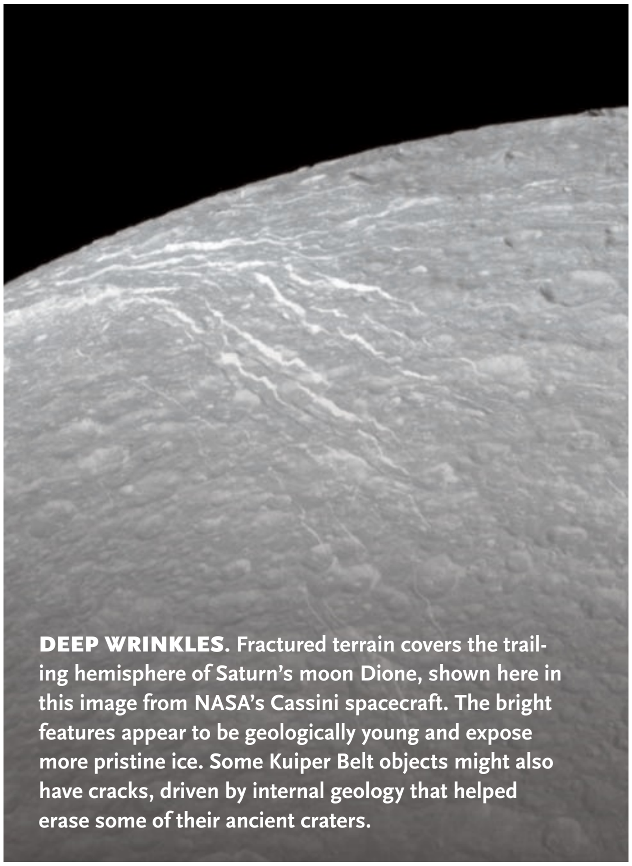
We now know enough about the sizes, albedos, and compositions to begin to develop an organized concept of the Kuiper Belt. The vast majority of objects are small (under 300 kilometers across), quite dark, and somewhat red. These are much too small to be dwarf planets and probably have changed little since they formed. They probably look a lot like Saturn's 220-km-diameter moon Phoebe, whose distant, retrograde orbit implies that it is almost certainly a KBO that was scattered inward by Neptune and then captured into its present position.



ALL IN THE FAMILY. The dwarf planets of the Kuiper Belt are a motley group. The colors and brightnesses shown are estimates by Alex Parker (University of California, Berkeley) based on the visible and near-infrared observations compiled in the Minor Bodies in the Outer Solar System database. Salacia and 2002 MS_4 are extremely dark, making their sizes uncertain: shown are potential diameters. The dark half of the Moon shows its albedo compared with the KBOs; the other half has been brightened to make familiar features visible.

The Cassini mission got a very good look at Phoebe on its way in to Saturn orbit and revealed it to be a battered, icy body showing signs of internal layering in its crater walls. Its surface displays a mixture of water ice, gunky organics, amorphous carbon, and rocky minerals. This cometlike combination of materials is a good match for the measured colors of the smaller KBOs, although scientists can't prove the kinship without better spectroscopic data.

Move up to the brighter (hence, larger) objects, though, and something changes. Brighter than absolute magnitude 5.6 — roughly equivalent to a diameter of 400 km — the surface composition changes. Whatever that composition change is, it makes the objects lighter in color. What could the difference be?



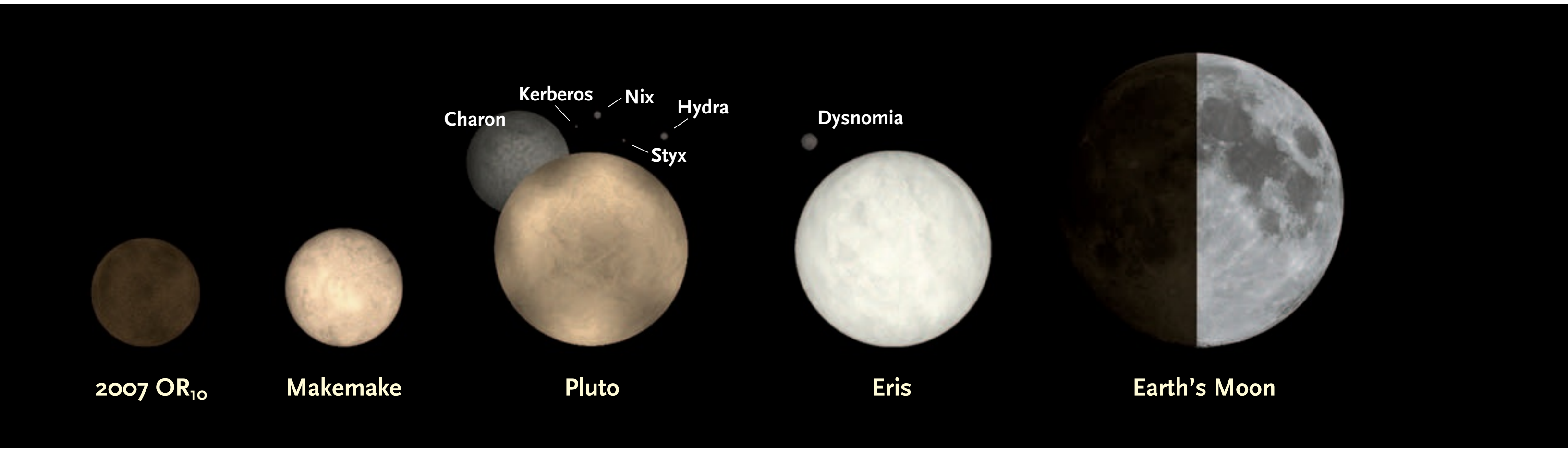
DEEP WRINKLES. Fractured terrain covers the trailing hemisphere of Saturn's moon Dione, shown here in this image from NASA's Cassini spacecraft. The bright features appear to be geologically young and expose more pristine ice. Some Kuiper Belt objects might also have cracks, driven by internal geology that helped erase some of their ancient craters.

NASA / JPL / SPACE SCIENCE INSTITUTE

Again, we can look at outer solar system moons for a clue. Under 400 km, we find objects such as Phoebe, Hyperion, Amalthea, and Puck, lumpy bodies shaped by their craters and passive slumps of surface material. Go larger than 400 km, and we are suddenly in the realm of the round icy moons, such as Uranus's Miranda and Saturn's Mimas and Enceladus.

Mimas is battered by craters but demonstrably round, and the surfaces of Miranda and Enceladus are clearly altered by internally driven geology (past or present) that has erased their ancient craters. It's tempting to think that a similar transition occurred on KBOs of the same size. Their self-gravity could have pulled them into round shapes, and they might have been just large enough for their heat of formation to melt some of their water — especially if they incorporated some ammonia, which lowers water's melting temperature. As they froze, their ice expanded, cracking near the surface and squirting pressurized "cryolava" (that is, liquid water) onto their surfaces, covering them with fresh, bright ice.

New Horizons's examination of Charon will provide the first close look at an object in this class. If the hypothesis is borne out by further examination — if these worlds are found to have enjoyed internally driven geology, and rounded themselves as a result — then they are all dwarf planets, and astronomers have already discovered more than a hundred of them.



S&T: GREGG DINDERMAN

The Biggest Dwarfs

Among the (possibly) hundred-plus dwarf planets of the Kuiper Belt are at least ten notable individuals. In order of their discovery, they are Pluto, Quaoar, 2002 MS_4, Sedna, Orcus, Salacia, Haumea, Eris, Makemake, and 2007 OR_{10}. They are big enough for spectroscopy to yield data on their surface compositions. They stand out not only for their size, but also for their striking variety.

Pluto is large enough to hold on to an atmosphere made of nitrogen, methane, and carbon monoxide. Although the atmosphere is thin, it suffices to provide Pluto with weather and a climate that varies dramatically with its changing distance from the Sun. Jeff Kargel (University of Arizona) has even suggested that Pluto might have a nitrogen cycle just as Titan has a methane cycle and Earth has a water cycle: liquid nitrogen could rain into rivers and lakes at certain times during Pluto's year! New Horizons will investigate.

We know that Pluto has patches of different-colored terrain on its surface, and that those patches have shifted with time. Pluto is also notable for its large companion, Charon, which would be a dwarf planet if it orbited the Sun on its own. Charon is large enough that light reflected from it will illuminate Pluto's nightside sufficiently for New Horizons to photograph Pluto by Charonlight.

Eris is a twin to Pluto in diameter but significantly more massive, suggesting its history was different from Pluto's. It's currently the most distant observed object orbiting the Sun (although Sedna is usually farther), discovered only because of its intrinsic icy brightness. The bright surface is most likely frost: Eris probably has an atmosphere like Pluto's when it's closer to the Sun, but at its current position (about three times farther from the Sun than Pluto is at the moment) all gases are frozen to its cold surface. Thus Eris provides a snapshot of what Pluto will probably look like in a century as it approaches aphelion, its atmosphere hibernating through the long orbital winter.

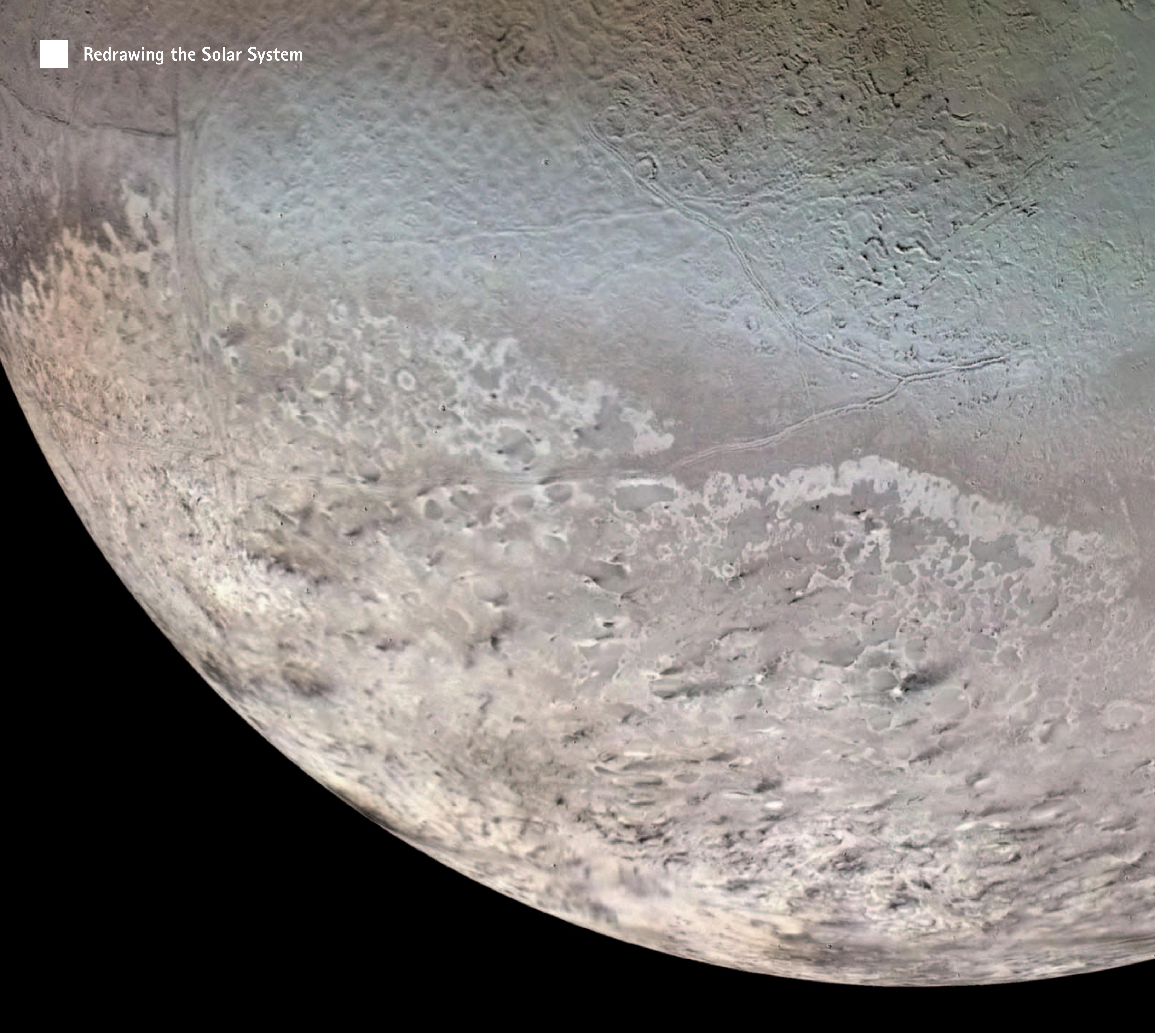
We can make a very good guess as to what Eris and Pluto look like by examining — you guessed it — an outer planet moon. Neptune's only large moon, Triton — which is larger than Pluto and nearly as big as Europa — has a bizarre-looking surface coated in bright frosts of nitrogen and methane. The resemblance between Triton, Pluto, and Eris is no accident: Triton almost certainly did not begin its existence circling Neptune. Its retrograde orbit, plus Neptune's curious lack of any other large moons, tells us that Neptune very likely captured huge Triton during its intrusion into the primordial Kuiper Belt. If Triton was independently orbiting the Sun, it, not Pluto or Eris, would be king of the Kuiper Belt.

At about half the diameter of Pluto and Eris, Makemake should have barely enough gravity to hold on to any nitrogen and carbon monoxide in its atmosphere. Its surface is dominated by methane, meaning that it must also have a methane atmosphere — at the ambient temperatures in this part of the solar system, methane ice will always have some gas above it, just as water ice on Earth always has some vapor above it. Peculiar shapes in Makemake's spectra suggest that its surface methane is not frost, but rather a solid slab of ice. The ice is dirtied with some amount of redder ethane and, very likely, smaller amounts of longer-chain hydrocarbons, much like those in Titan's atmosphere, only in solid form.

Quaoar and 2007 OR_{10}, somewhat smaller than Makemake, are similar in size and color. Their surfaces are known to bear methane ice or frost in a patchy coating on a mostly water-ice surface. So they, too, must have methane atmospheres, although these haven't been detected yet.

Sedna, too, bears methane. Sedna is similarly sized to Makemake, but much more distant. It never gets closer than 76 a.u. from the Sun — more than twice Neptune's distance. And its long, long orbit will eventually take it, 5,000 years from now, to an amazing 1,000 a.u. away.

Orcus, smaller and grayer than Quaoar and 2007 OR_{10}, shows tantalizing hints of ammonia on its surface. Geophysicists often invoke ammonia to explain long-lasting subsurface oceans on icy worlds (such as Europa),



because ammonia lowers water's freezing point. Ammonia on Orcus indicates that cryovolcanism has happened there. Like Pluto, it has an outsized companion, Vanth, more than a third Orcus's diameter.

Haumea is an odd duck. It's the fastest-rotating and most elongated, big round object in the solar system, with a day lasting only four Earth hours. It's one of the largest KBOs, about as wide as Pluto and Eris along one of its equatorial axes but only half as tall pole-to-pole. It has a bright surface of nearly pure, crystalline water ice, and so do its moons, Hi'iaka and Namaka. A whole family of smaller, similarly bright, crystalline icy objects follow orbits like Haumea's. These are probably bits of Haumea's mantle, shrapnel from an ancient collision that smashed away Haumea's crust, set the world spinning fast, and launched icy chunks into their own solar orbits.

Two more enigmatic worlds — 2002 MS_4 and Salacia — might belong on this list of dwarfs, too. Not much is known about them yet, except that they are extremely dark (see diagram, page 22). They might mark the extent of the major dwarf planets, at least for now: a recent search of the Southern Hemisphere sky netted no discoveries of other large objects, and work suggests that the inventory of large, bright KBOs is nearly complete.

NASA / JPL / USGS

CAPTURED KBO. Voyager 2 captured the images combined in this enhanced-color mosaic of Neptune's moon Triton. The moon's surface is mostly nitrogen ice, and the pink deposits might be created by sunlight-induced reactions in methane ice. Triton is probably a Kuiper Belt object caught by Neptune when the planet migrated outward early in the solar system's history.

The New Solar System

So here is my new mental picture of the solar system. We still have eight major planets on their sedate, nearly circular, nearly coplanar orbits. Jupiter herds a large family of little, lumpy asteroids in the main belt.

Beyond Neptune is another belt, this one made of several distinct but overlapping populations of worlds big enough to have their own unique histories. Don't imagine this belt as kin to the asteroid belt. It's more like a scattering of outer planet moons. Think of things like Triton, Rhea, Mimas, and Phoebe, some of them traveling in circles, others in wild, tilted ellipses, moving slowly when far from the Sun but more speedily when they're near Neptune's orbit.

These trans-Neptunian worlds far outnumber the 18 or so round icy moons of the outer planets. Think for a moment about how varied the appearances of these moons are, and then extrapolate that variety to the more than 100 spherical dwarfs wandering the vast region of trans-Neptunian space.

Some of these objects are as bright as Tethys, some darker than Umbriel. Some are gray, some red, some frosty white, some patchy. Several have atmospheres, with wind, weather, and seasons. Many have moons. A few of these moons are big enough to be included in our count of dwarf-planet-like moons.

They may not orbit a planet, but Neptune controls them all. Some travel to enormous distances from the Sun, but they always return to Neptune's neighborhood. Except one: Sedna.

Sedna's remarkably different orbit raises all kinds of questions. How did it get its elongated orbit way out there? Is it alone? Or is it analogous to Pluto, the easiest-to-find member of a whole new, unexplored population of objects? Does our Sun have another, much more distant planetary companion, herding an as-yet-undiscovered third belt of worlds?

One thing is certain: we have just barely begun the exploration of this wilderness in our planetary backyard, and there are many more worlds yet to find. It's almost certain that there are more bodies larger than Pluto, and it's in the realm of possibility that there's something as big as Neptune lurking out there, beyond our current ability to spot it (*S&T*: March 2010, page 20).

KBOs are dim, distant, and difficult to study. But let's not shrink from their great distance and bewildering variety by dropping Pluto from the record and telling kids that our solar system ends at Neptune. Pluto, Quaoar, Orcus, Haumea, Makemake, 2007 OR_{10}, Salacia, 2002 MS_4, Eris, and way-out Sedna are each unique and fascinating worlds, and they deserve places in our mental maps of our astronomical home.

And while we're adding round worlds to our kids' solar system posters, let's also include Ceres, Io, Europa, Ganymede, Callisto, Mimas, Enceladus, Tethys . . . ✦

Sky & Telescope *contributing editor* ***Emily Lakdawalla*** *is senior editor and planetary evangelist for The Planetary Society. She writes about space science and exploration at* ***planetary.org***.

Galactic Depth Perspective

OBSERVING THE MILKY WAY, PART III

Perseus to Puppis & Beyond

The winter Milky Way is faint and vague, but it's adorned with some of the finest clusters and nebulae in the sky.

Craig Crossen

The first article in this series, in the July 2013 issue, examined the central section of our galaxy, in Sagittarius and Scorpius. The second, in October 2013, traced the glowing band from Scutum to Cassiopeia. Now we will complete the circle with the Milky Way that arcs overhead during northern winter evenings and the far-southern Milky Way from Carina to Norma.

Around the times and dates listed in the all-sky map on page 44, observers at mid-northern latitudes can see the Milky Way as a great bow of pale haze. It sweeps out of Cepheus, low in the north, up through Cassiopeia and Perseus in the northwest to Auriga, which is more or less overhead. From Auriga, the winter Milky Way descends between Gemini and Orion, passes through faint Monoceros, streams over the back of Canis Major, and finally is lost to horizon haze in Puppis, low in the southeast. During the next few hours, Puppis rises a little higher in the south, and the rest of the Milky Way arch descends slowly toward the western horizon.

But you might not be able to see this clearly unless you have very dark skies. Unlike the bright Milky Way of summer and early fall, the winter Milky Way is just a pale, glowing band. Moreover, it has very ambiguous edges and displays no conspicuous bright star clouds or dark dust features. At best you can see areas of slightly enhanced glow, the brightest being in central Auriga, central Monoceros, and Puppis.

The essential reason for the different appearance of the Milky Way in summer and winter is that in summer we look inward toward our galaxy's dust- and star-rich central region. In winter, by contrast, we look away from the central regions, through the thin outer disk of our spiral galaxy. The galaxy's center (galactic longitude and latitude 0°) is in extreme western Sagittarius, and the anticenter (longitude 180°, latitude 0°) is located on the Taurus-Gemini border 3½° east of Beta (β) Tauri, the star also known as Elnath. By amazing coincidence, the galactic anticenter is just 6° west of another very special spot in the sky: the northernmost point on the ecliptic.

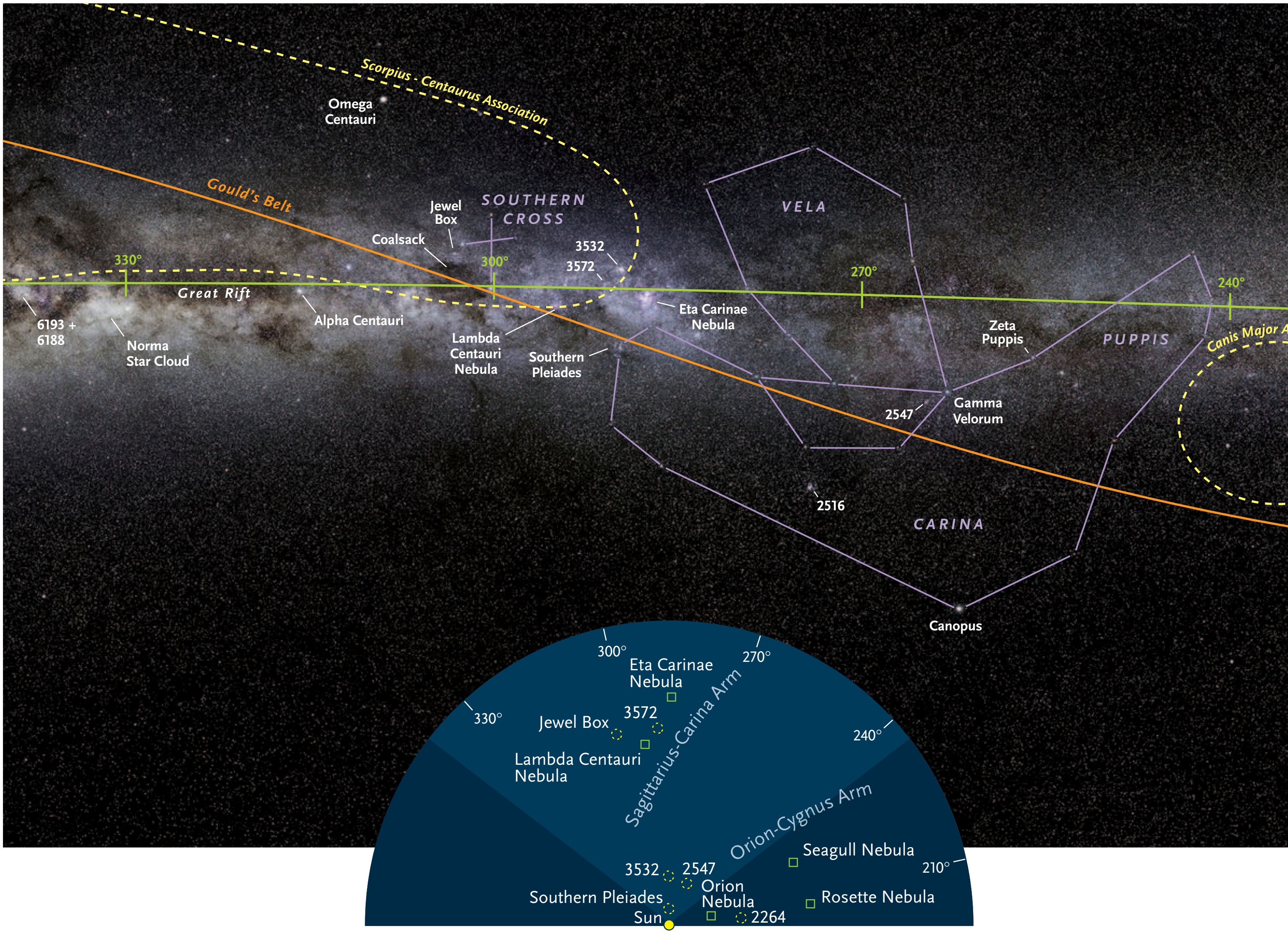
At the sidereal time shown on our all-sky map, the galactic anticenter is near the zenith for mid-northern observers. So if you stand facing west, galactic longitude 90°, which is close to Deneb in Cygnus, will be on your right, near the north point of your horizon. This is the direction of galactic rotation; the stars in the Sun's neighborhood are heading toward Deneb as they orbit the galaxy's center. (But Deneb is orbiting in roughly the same direction, so the Sun won't catch up with it anytime soon.)

On your left as you face west, near the south point of the horizon, is galactic longitude 270°. This is the direction from which the Sun and its neighbors have come. So in terms of galactic rotation, when you look north from Elnath along the winter Milky Way, you're looking *forward* as well as out of our galaxy. And when you scan south along the winter Milky Way, you're looking *backward* and out.

Our Orion-Cygnus Spiral Arm

Our solar system is currently passing through one of our galaxy's lesser spiral arms, which is called (among many other aliases) the Orion-Cygnus Arm, Local Arm, Orion

AKIRA FUJII



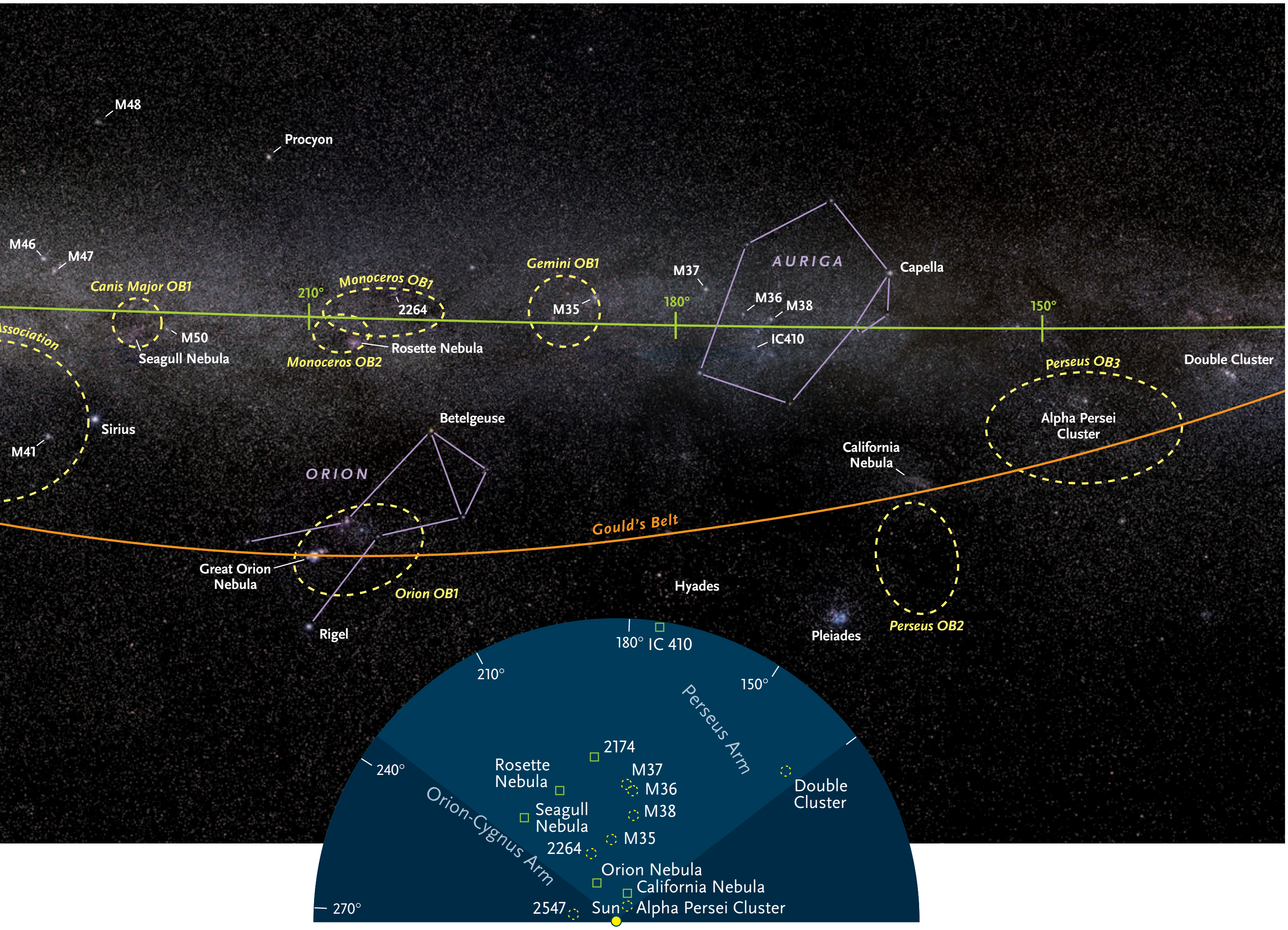
The chart at top shows more than half the Milky Way, from galactic longitude 130° in Perseus to 340° in Norma. The semi-circular charts under it show how selected Milky Way objects are distributed along the galactic plane. The outer edges of the blue semicircles are 10,000 light-years from the Sun.

Arm, or Orion Spur. We're located near this arm's inner edge. So when we view the winter Milky Way, we're looking out through the core of the Orion-Cygus Arm, which lies between us and the galactic rim. That's why so many relatively nearby open clusters, stellar associations, and emission nebulae adorn the Milky Way from Perseus to Canis Major.

Beginning with Perseus, which is currently high in the northwest, we find the Alpha (α) Persei Cluster, which lies some 550 light-years away in the center of the Perseus OB3 Association. The Zeta (ζ) Persei Association (also called Perseus OB2) and its neighbor the California Nebula (NGC 1499) are roughly 1,000 light-years distant.

In Taurus, above the west-northwest horizon, are the Pleiades and Hyades clusters, 400 and 150 light-years from us, respectively. To the west-southwest is the mighty Orion Association, centered some 1,500 light-years away. Low in the southwest, perhaps 2,500 light-years distant, is the Canis Major Association (Collinder 121), which includes 2nd-magnitude Delta (δ) and Eta (η) Canis Majoris as well as 3rd- and 4th-magnitude Omicron^1 (o^1), Omicron^2 (o^2), and Sigma (σ) Canis Majoris.

Except for the Alpha Persei Cluster, all of these objects lie well below the hazy stream of the winter Milky Way itself and therefore seem pendant from it. Sprinkled among these clusters and associations, along the same band from Perseus to Canis Major, are a large number of 2nd- to 4th-magnitude, blue, early-*B* stars — both main-sequence and giants — that are all several hundred light-years distant. They include Delta and Epsilon (ε) Persei; Zeta and Lambda (λ) Tauri; Gamma (γ) Orionis; Beta Monocerotis; and Beta, Epsilon, and Zeta Canis Majoris. This suggests that these stars, and the



S&T: GREGG DINDERMAN, BASE PHOTO: SERGE BRUNIER

clusters and associations behind and among them, have some actual astronomical connection. And so they do.

Gould's Belt: The Foreground of Our Spiral Arm

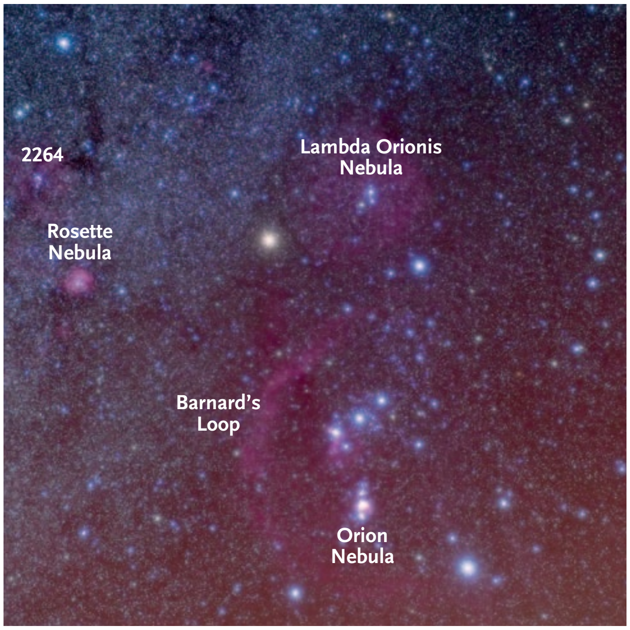
Let's establish some terminology before discussing the structure of the nearby Milky Way. Our galaxy's spiral arms lie in a thin, spinning disk. The *galactic equator* — the nearly straight line across the star chart above — traces the central plane of that disk. Looking at right angles to that plane, along the galaxy's spin axis, we reach the *north galactic pole*, which lies just east of the Coma Berenices Star Cluster, and the *south galactic pole*, which is in Sculptor 2° southeast of the spectacular galaxy NGC 253.

The nearby associations, clusters, and nebulae from Perseus to Canis Major lie "below" the plane of the Milky Way, on the galactic-south side of the equator.

But the nearest stellar association of all, the 70°-long Scorpius-Centaurus Association, lies "above" the Milky Way plane, on the galactic-north (Coma Berenices) side of the equator. That's particularly obvious from the Southern Hemisphere, where the entire Scorpius-Centaurus Association is in plain view for much of the year. North of the tropics, parts of this association are never visible at all, and the rest can be seen only low in the summer sky.

So when we look toward the galactic interior from Scorpius to Centaurus, most of the luminous nearby stars appear above the plane. And when we look away from the galactic center, between Perseus and Canis Major, they appear below the galactic plane. This fact was noticed in the 19th century, first by the great English astronomer John Herschel during his stay in South Africa and then by the great American astronomer Benjamin Gould from his station in Argentina. As both astronomers noted, it hints that these stars lie in a thin sheet or ring that's tilted slightly with respect to the plane of the Milky Way — a structure now known as *Gould's Belt*.

The star chart above shows the approximate centerline of Gould's Belt as an orange line stretching from Perseus



Orion, home to some of the most vigorous nearby star-forming regions, lies south of the main Milky Way belt. Most of the pink hydrogen-alpha glows in this photograph indicate ongoing star formation. Barnard's Loop is probably a supernova remnant. Stars massive enough to produce supernovae are short-lived, so supernova remants are also tracers of recent star formation.

to Crux; you can see it across the entire Milky Way on the star chart in the center of the July 2013 issue.

Gould's Belt is tilted about 17° with respect to the galactic equator, crossing it in Crux and Cassiopeia. It's a small part of the Orion-Cygnus Arm — a local feature. The arm also contains some more distant clusters, associations, and dust clouds, which tend to lie close to the galactic equator.

The true space center of Gould's Belt is in the vicinity of the Alpha Persei Cluster. The Sun is within the belt about halfway between the Alpha Persei Cluster and the belt's interior edge near the Rho (ρ) Ophiuchi complex. Radial velocity and proper motion studies have found that the objects around the periphery of Gould's Belt are moving outward from a common center at about 6 miles (10 km) per second. Given the belt's present size, this suggests that the expansion began some 70 million years ago, consistent with the estimated age of the Pleiades and Alpha Persei clusters, both of which are near the belt's center and therefore probably among its oldest clusters.

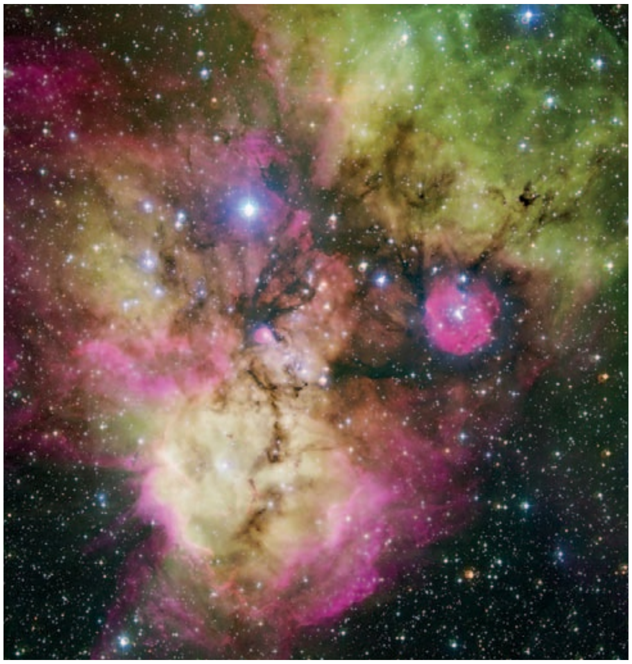
One hypothesis is that roughly 70 million years ago a supernova exploded in the vicinity of the dust cloud that was to become the Alpha Persei and Pleiades clusters. That event initiated star formation there, and the process has been expanding outward in a ring ever since. At present the most vigorous star formation in Gould's Belt is occurring in the Orion Nebula, the IC 348 nebula in the Zeta Persei Association, and the Rho Ophiuchi complex near the Scorpius-Ophiuchus border.

Beyond Gould's Belt

Thus when we look toward the winter Milky Way proper, along the galactic equator from Auriga to Puppis, we are in fact looking "over" Gould's Belt, which is a foreground structure within our Orion-Cygnus Arm. Beyond the belt, along the winter Milky Way itself, is a series of young stellar associations and open clusters with involved emission nebulae and dark dust clouds that can be thought of as tracing the core of the Orion-Cygnus Arm. They're all rather distant, from 3,000 to 5,000 light-years away, so they're not naked-eye objects. But some of these clusters and nebulae are easily visible in binoculars.

Tracing the winter Milky Way down from the zenith, the first bright Orion-Cygnus complex that we encounter is the Gemini OB1 Association, which is on the Gemini-Orion border between Castor's feet and the end of Orion's club. Gemini OB1 is about 5,000 light-years away and includes Chi^2 (χ^2) Orionis and the emission nebula NGC 2174, an object easily found with 10×50 binoculars 2° southwest of Eta Geminorum.

The next Orion-Cygnus Arm tracer down along the winter Milky Way is NGC 2264, the "Christmas Tree Cluster," which is in extreme northern Monoceros 3° south and slightly west of Xi (ξ) Geminorum. This cluster is 20′ long and is an easy 10×50 binocular target — though its south-pointing arrowhead shape can be a bit tricky to pick out from its rich star field. The 4.5-magnitude blue giant variable S Monoceroti is on the north end of the cluster, marking the Christmas Tree's trunk. NGC 2264 is part of the Monoceros OB1 association, which is centered about 2,500 light-years from us.



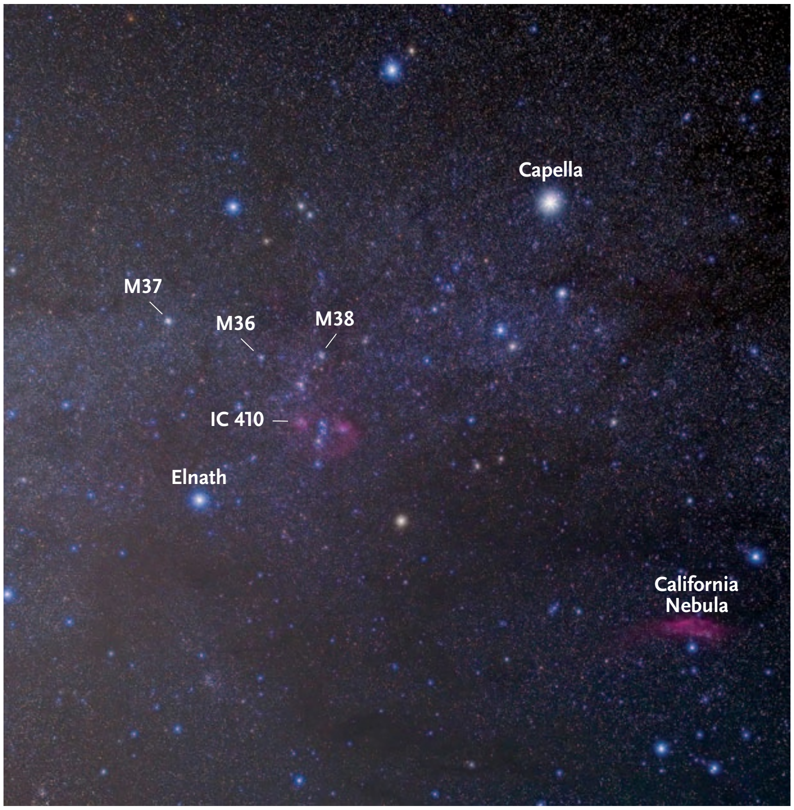
The emission nebula NGC 2467 is visible in binoculars and small telescopes even though it's more than 15,000 light-years away.

Also in northern Monoceros, about 5° south-southwest of NGC 2264 and 8° east-southeast of Betelgeuse, is the Rosette Nebula, whose brightest components have three separate NGC numbers: 2237, 2238, and 2246. It's surprisingly easy to spot with 10×50 binoculars under a dark sky.

At the center of the Rosette is the 20′-long rectangle of the open cluster NGC 2244. Although this 4.8-magnitude cluster is visible to the naked eye as a cloudy smudge, it can be difficult to identify through telescopes and binoculars despite its distinctive rectangular shape (with 6th-, 7th-, or 8th-magnitude stars at each corner, and in the middle of both long sides). It's not particularly populous and can be lost in its rich Milky Way star field. Many of these field stars are members of the Rosette's association, Monoceros OB2, centered about 4,500 light-years away. Others are members of Monoceros OB1, which is much closer in space but overlaps Monoceros OB2 in the sky.

Some 20° further southeast along the winter Milky Way from the Rosette, past the central Monoceros Milky Way glow, is the 4,500-light-year-distant Canis Major OB1 Association, which includes the populous open cluster NGC 2353 and the Seagull Nebula, IC 2177, both visible in giant binoculars. The easy binocular open cluster M50, just to the northwest of the Canis Major OB1 complex, is only 3,000 light-years away, so it must be an unrelated foreground object.

Finally, the compact open cluster NGC 2362 lies 15° due south of the Canis Major OB1 Association and 2½° northeast of Delta Canis Majoris. Its brightest star is 4.4-magnitude Tau (τ) CMa. NGC 2362 is a very young cluster, just a few million years old, and is therefore a true Orion-Cygnus Arm tracer. It is 4,500 light-years away, about twice the distance of Delta Canis Majoris, which is the brightest member of the Canis Major Association, a Gould's Belt object. Because in this direction we look toward about galactic longitude 240°, NGC 2362 can be thought of as "following" the Canis Major Association in terms of galactic rotation.



This field in Auriga and Perseus contains objects at a wide range of distances. The California Nebula is a Gould's Belt object, roughly 1,000 light-years away. The Messier clusters in Auriga are in the main Orion-Cygnus Arm, 3,500 to 4,500 light-years distant. And IC 410, which appears near M36 and M38 in the sky, is at least 10,000 light-years distant, in the Perseus Spiral Arm.

The Perseus Arm in the Winter Milky Way

The major Orion-Cygnus Spiral Arm tracers from Auriga down to Canis Major and Puppis are fairly widely spaced. This reflects the fact that the interstellar dust clouds from which young open clusters and stellar associations condense are more widely spaced in the outer galaxy than they are in the galactic interior toward the summer Milky Way. The dust is very thin between the complexes of stars and nebulae, giving us long, relatively clear views beyond the Orion-Cygnus arm into the outer galaxy. Large dust-free windows lie in central Auriga, central Monoceros, and central Puppis. In these windows, the Milky Way glow is distinctly brighter to the unaided eye, and binoculars reveal rich fields of faint stars sparkling on the Milky Way haze.

The Auriga, Monoceros, and Puppis windows allow us to trace the Perseus Spiral Arm far out toward the galaxy's rim. The Perseus Arm, which is so conspicuous in the Cassiopeia Window of the autumn Milky Way, is lost to view east of the Perseus Double Cluster, hidden behind the Gould's Belt dust clouds of southern Perseus and northern Taurus. However, we pick up the Perseus Arm once again in central Auriga with the complex containing the open cluster NGC 1893 and the emission nebula IC 410. Although they're at least 10,000 light-years away, the combined glow of NGC 1893 and IC 410 is visible in 10×50 binoculars as a very pale patch of haze about 20′ across.

Past Auriga, the Perseus Arm arcs out toward the galaxy's rim, so the Perseus Arm tracers in central Monoceros and central Puppis are increasingly distant and faint. Most are invisible through binoculars and small telescopes. One exception is the nebula NGC 2467 (shown on the facing page), about 1° southeast of Omicron Puppis. This object, though more than 15,000 light-years away on the outer arc of the Perseus Arm, can be seen in 10×50 glasses as a small but moderately bright disk of haze.

The Far-Southern Milky Way

The far-southern Milky Way contains some very famous and spectacular objects, including the Southern Cross, the Coalsack, the Jewel Box Cluster (NGC 4755), and the incomparable Eta Carinae Nebula (NGC 3372). Unfortunately, this stretch of the Milky Way never rises above the horizon for observers significantly north of the tropics. But on spring evenings — or after midnight in February — it's possible for a mid-northern observer to get some idea how the far-southern Milky Way links up with the section that's visible from the Northern Hemisphere.

The key to "observing" the invisible far-southern Milky Way is the conspicuous spring constellation Corvus, the Crow, which is directly north of Crux, the Southern Cross, about halfway between Crux and the celestial equator. Thus as Corvus transits your meridian, Crux will be directly below the south point of your horizon by a distance that depends upon your latitude. At the same time, the southernmost constellations of the Northern Hemisphere's winter Milky Way — Monoceros, Canis Major, and Puppis — will be setting in your southwest. And Scorpius, the southernmost constellation of our summer Milky Way, will be rising in your southeast.

The Scorpius-Centaurus Association extends from Scorpius on the northeast through Crux on the southwest. So when Corvus is at its highest, you can get some idea of the extent and shape of the Scorpius-Centaurus Association by imaginatively tracing it from Scorpius in your southeast to Crux beneath the south point of your horizon.

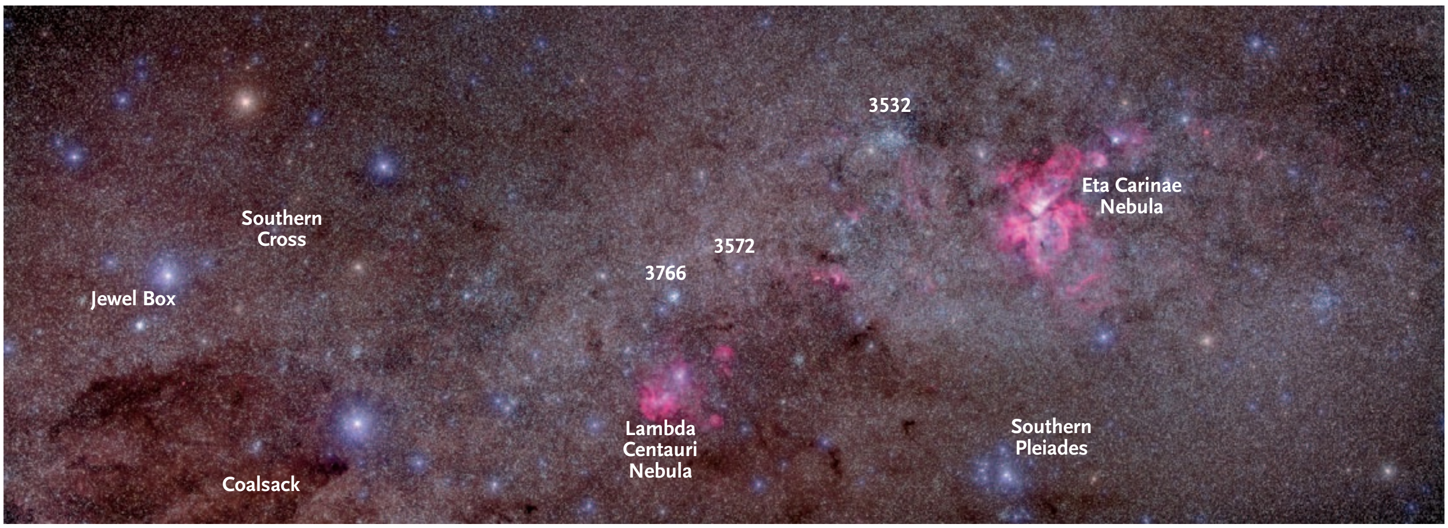
In Crux is the famous Coalsack dark cloud, which is about 5° across. It lies 10° past the southern end of the Great Rift, which runs down the center of the Milky Way from Cygnus to Centaurus. Nonetheless, the Coalsack seems to be a Great Rift outlier. It's some 550 light-years distant and 60 light-years across. Despite its apparent density, no star formation is currently taking place within it. But the Coalsack is not quite as dense as it looks. It actually obscures the stars behind it by a rather modest 2½ magnitudes, but it looks virtually opaque because it's silhouetted upon a particularly bright star cloud.

The Scorpius-Centaurus Association and Great Rift mark the galactic interior edge of our Orion-Cygnus Spiral Arm. Beyond their eastern end we look across an interarm gap, poor in dust and open clusters, at the next spiral feature in from ours: the Sagittarius-Carina Arm, which extends from the Scutum Star Cloud on the northeast to the Eta Carinae region on the southwest. The star clouds around the Eta Carinae Nebula are exceptionally bright and rich for two reasons. First, the Sagittarius-Carina Arm here arcs out toward the galactic exterior, giving us a long view down its heart. And second, much of the interstellar dust in this stretch of the Sagittarius-Carina Arm seems to have been used up in star formation, providing us with an exceptionally clear view along it.

Several windows through the dust clouds of the Sagittarius-Carina Arm give us glimpses of the next spiral feature toward the galactic bulge: the Norma Spiral Arm (sometimes called the Scutum-Centaurus Arm). The northeast edge of the Norma Arm is at the Scutum Star Cloud, where it and the Sagittarius-Carina Arm seem to merge as they curve in around the galactic bulge. The Small Sagittarius Star Cloud, M24, is probably another stretch of the Norma Arm. The arm's name comes from the brilliant Norma Star Cloud in the southern part of that otherwise inconspicuous Milky Way constellation. Finally, the bright star clouds upon which the Coalsack is silhouetted probably lie on the southwest, outcurving edge of the Norma Arm.

One of the major unanswered questions about the local spiral structure of our galaxy concerns our own Orion-Cygnus Arm. Its course is clear in the neighborhood of the Sun, and it extends forward (in terms of

With a profusion of bright nebulae and rich open clusters, the area around the Eta Carinae Nebula and Southern Cross rivals the Sagittarius-Scorpius border for the title of "most spectacular region of the Milky Way." Both regions contain objects at a wide range of distances along the same line of sight.



ALAN DYER

The southern Milky Way arches over Iguazu Falls on the Argentina-Brazil border. The Magellanic Clouds are visible under the arch on the left.

BABAK TAFRESHI

galactic rotation) to the Cygnus Star Cloud, which lies between galactic longitudes 60° and 80°.

But we look at a puzzle in the opposite direction, between galactic longitudes 240° and 260° in Puppis, Pyxis, western Vela, and western Carina. We would expect that in this direction we would be looking along the outcurving arc of our Orion-Cygnus Arm and would therefore see many young open clusters and emission nebulae — and perhaps another star cloud to match the one in Cygnus. In reality we see relatively few stars and just a smattering of open clusters, most of them quite old, and therefore not true spiral-arm tracers. There aren't any hidden star-forming regions; this is one of the most dust-free directions along the Milky Way plane, with as little as 3 magnitudes of absorption all the way out to the rim of the galaxy toward central Puppis.

But the plot thickens in Vela between galactic longitudes 260° and 270°. Here we would expect to see a dust- and cluster-poor interarm gap between the outcurving arcs of the Orion-Cygnus and Sagittarius-Carina arms. Instead, we find ourselves looking at a confusing clutter of dust clouds, young open clusters, and stellar associations. The nearest associations, which include the young, hyperluminous stars Zeta Puppis and Gamma Velorum, are well south of the galactic equator, so they are presumably features of Gould's Belt. But there are also clusters, associations, and nebulae at a wide range of distances right on the galactic equator.

One plausible explanation is that toward Vela we look along a bridge that joins our Orion-Cygnus Arm to the outcurving arc of the Sagittarius-Carina Arm. Or perhaps the entire Orion-Cygnus Arm is bending inward here. But for the moment all this remain uncertain. ✦

Craig Crossen *is a traveler, writer, and academic editor who calls Minnesota home. He is currently finishing books on the ancient Mesopotamian constellations and the history of archaeology in Iraq.*

NORTH CAROLINA MUSEUM OF ART, RALEIGH; PURCHASED WITH FUNDS FROM THE STATE OF NORTH CAROLINA

Dating an Impressionist's Sunset

Donald W. Olson
Russell L. Doescher
Laura E. Bright
Hannah N. Reynolds
Ava G. Pope

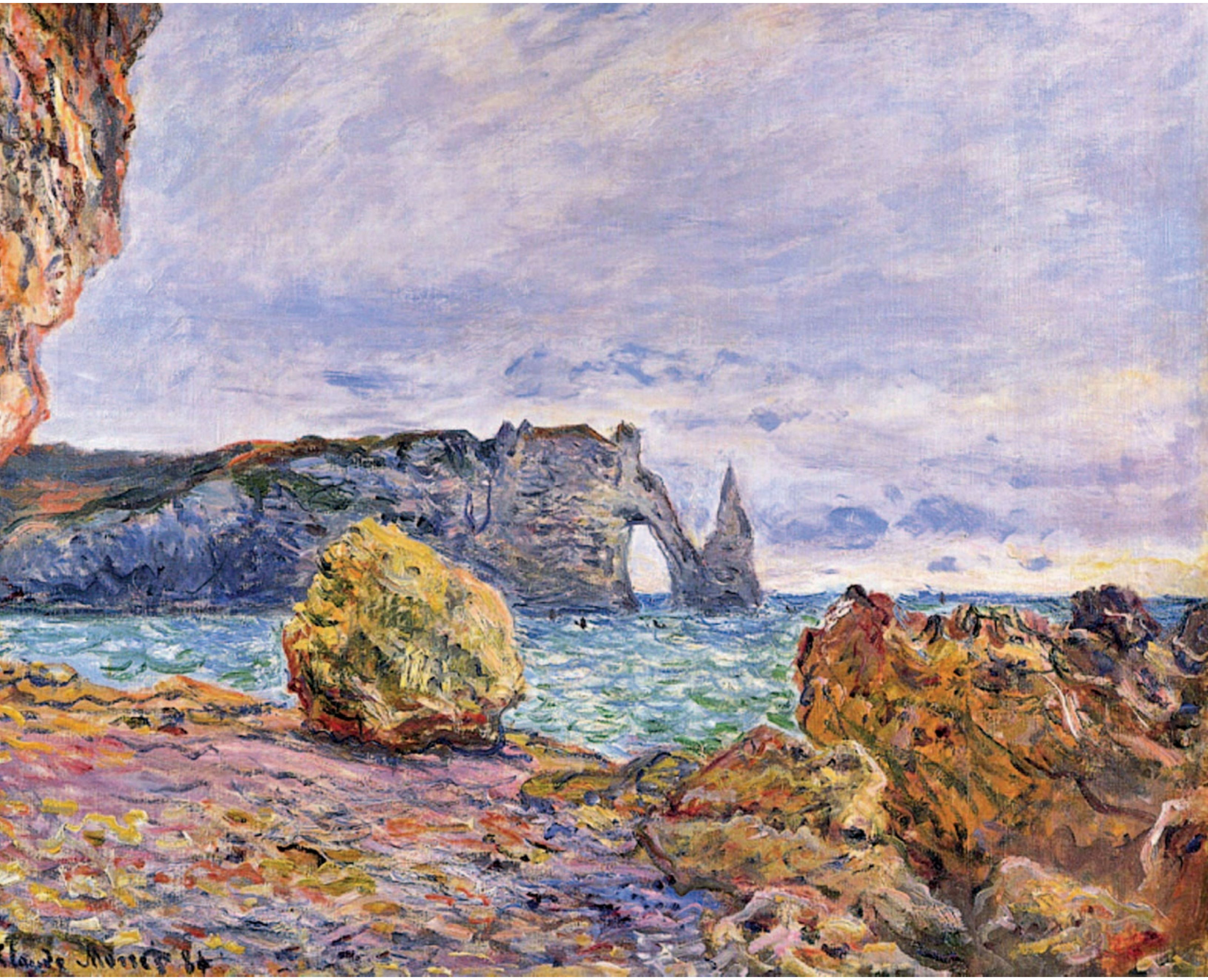
A team of celestial sleuths has pinned down the exact time and location of one of Claude Monet's most beautiful paintings.

When associating a painting with a moment in time, many people simply assume that painters just put in the Sun or Moon where it looks good. Some do, but other artists are committed by their personal beliefs or artistic sensibilities to convey nature, including the sky, exactly as they see it at the very moment they depict it.

The Impressionists — the painters of light — are among the most notable because they took their easels into the scenes they were painting and experimented with techniques that could show the passing effects of the Sun and shadows. They traveled to places where clear air and sparkling water challenged their skills. The Impressionists' enduring popularity is partly based upon the beautiful scenery conveyed in their paintings.

Claude Monet (1840–1926), whose painting *Impression: Sunrise* gave the name to this artistic movement, traveled and recorded more than 80 scenes on the Normandy coast near the popular resort town of Étretat. The physical locations near Étretat are daunting, with steep trails on towering chalk cliffs

ÉTRETAT: SUNSET **The position of the Sun, the level of the tides, Normandy weather observations, and Monet's letters enabled the Texas State University team to determine the exact date and location for this striking sunset painting by the great French Impressionist Claude Monet. The central arch is known as the Porte d'Aval (Downstream Portal) and just to its right, but more distant, is the Aiguille (Needle).**



WIKIPAINTINGS

and beaches that flood dangerously at high tide. Conjuring an image of Monet, loaded with bulky painting equipment, scrambling up and down and wading in seaweed, brings him and the moment of artistic creation very close in our imaginations.

The Impressionists lived to capture the transitory effects of the Sun, sky conditions, and tides. Monet himself emphasized the importance of these factors in a February 1883 letter from Étretat to his future wife Alice Hoschedé: "I need the Sun or the cloudy weather to coincide again with the tide, which must be low or high in accordance with my motifs."

ÉTRETAT: THE BEACH AND THE PORTE D'AVAL Monet returned to nearly the same spot sometime in 1884 to paint this daytime scene. Based on the way the arch overlaps the Needle, Monet's location for this painting must be very near the spot where he created the sunset view in 1883. The limestone blocks in the foreground were deposited in 1882 by a major rockfall from the Amont cliff, which overhangs the beach at this point.

The paintings from Étretat are among Monet's best, so art historians have tried to date them and find their locations. Fortunately, Monet was accurate about his painted skies. Moreover, Claude Monet wrote letters almost daily, and Étretat has famous identifiable locations. But decades of study have yielded a disparity of opinions concerning the dates and locations, without convincing and precise findings. We know from his letters that Monet journeyed to Étretat in late January 1883 for a painting campaign of several weeks. Thinking that the movements of the tides and celestial bodies, in conjunction with historical research, could yield some firm results, our Texas State University group attempted to date the precise moment that inspired the dramatic painting *Étretat: Sunset*.

One Location, Two Paintings

This canvas, with the signature and year "Claude Monet 83" at the lower left, shows a spectacular line of cliffs and rock formations to the southwest of Étretat. The Sun is sinking near a limestone arch known as the Porte d'Aval and a tall, pyramid-shaped rock just offshore called the Aiguille (Needle). By looking carefully at the way the arch overlaps the more distant Needle, we could use parallax to determine exactly where Monet set up his easel.

Another canvas, titled *Étretat: The Beach and The Porte d'Aval*, shows the scene in daytime and bears the signature and year "Claude Monet 84." In both paintings, the horizon line passes through the Needle at nearly the same elevation, and the Porte d'Aval arch overlaps the Needle almost identically, proving that Monet's location for the sunset view must have been on the beach and very near the spot where he created the daytime view. Although the sunset painting features only water in the lower half of the canvas, the foreground of the 1884 work helpfully includes topographic details near Monet's location on the Amont beach that extends to the northeast of Étretat. The daytime painting shows the Amont cliff overhanging on the left, along with large rocks that have come loose from the cliff overhead and fallen to the beach.

According to art historian Robert Herbert, Monet must have viewed the daytime scene from a location near the small arch called the Porte d'Amont at the extreme northeast end of the Amont beach, out where the Amont cliff projects into the English Channel. In his 1994 book *Monet on the Normandy Coast*, Herbert suggests that Monet set up his easel ". . . inside the bay a few yards from the forward point of the promontory, to paint *Étretat: The Beach and The Porte d'Aval*."

Trip to Étretat

To carry out an independent analysis of the location and date, our Texas State group, accompanied by *S&T* senior contributing editor Roger Sinnott, spent five days in Étretat in August 2012.

Our group of celestial sleuths stayed at the Detective Hotel in rooms named after famous fictional detectives: Sherlock Holmes, Inspector Clouseau, Charlie's Angels, Columbo, and Hercule Poirot. Another room honors the character Arsène Lupin in *The Hollow Needle*, a novel by Maurice Leblanc in which Lupin discovers that the Étretat


WIKIPAINTINGS

IMPRESSIONIST Claude Monet created this self-portrait in 1886, just a few years after his series of paintings from Étretat.

Aiguille contains a hidden treasure room filled with gold and precious gems belonging to the kings of France. Inspired by these examples, our sleuthing on the beach and cliffs revealed dozens of Monet painting locations.

We visited the spot described by Herbert. As we walked northeast along the beach, it quickly became apparent that Herbert's suggested location for the sunset painting could not be correct. As seen from near the forward point of the Amont promontory, the Porte d'Aval arch does not overlap the Needle at all. The Needle appears free-standing and detached, well to the right of the Porte d'Aval arch, with open water in between. Monet could not have created the sunset and daytime paintings from this spot.

We then walked systematically from one end of the beach to the other. Our digital photographs matched the two painted views only from one point on the Amont beach, near the coordinates 49.7112° north, 0.2044° east.

Herbert had suggested that Monet set up his easel on the Amont side, "inside the bay a few yards." Our Texas State group found that the correct location is 425 yards (390 meters) from the seaward end of the Amont promontory. The limestone cliff still overhangs this location, and rocks still come loose and fall to the beach.

Moonset: Étretat

Monet created his sunset painting in the winter, but university calendars dictated that our research trip take place in August. The position of our summer sunsets could not match the winter sunset observed by Monet. But we arranged our trip so we could photograph the waxing crescent Moon on several evenings as it passed just to the right (north) of the Needle, not far from the region of the sky where Monet painted the solar disk. After moonset, we could photograph stars near the Aval cliff.

Prior to our trip, we had corresponded with the local astronomy club, the Société Astronomique du Havre. Club member Jean Langlois took a series of February sunset photographs from various spots on the Amont beach. Analyzing all of these photographs, we determined that the setting Sun would match the position in Monet's sunset painting only when the solar declination was near –16°. Using computer planetarium programs to reconstruct the 19th-century sky, the best fit occurred on February 5, 1883. Allowing for some uncertainty, we are confident that Monet's sunset scene corresponds to a date between February 3 and February 7, 1883.

The Perfect Match

To determine the precise date, we calculated solar and lunar positions and the resulting Étretat tide levels in February 1883. Normandy is famous for its remarkable tides, with a mean range near Étretat of about 18 feet (5.5 meters), a spring range of about 24 feet near new or full Moon, and extreme tide ranges that can reach 28 feet near the equinoxes if a new or full Moon happens to coincide with a lunar perigee (when the Moon is closest to Earth).

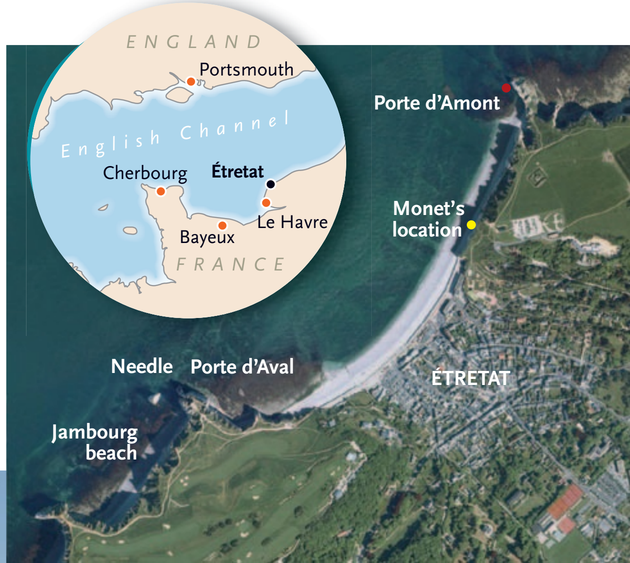
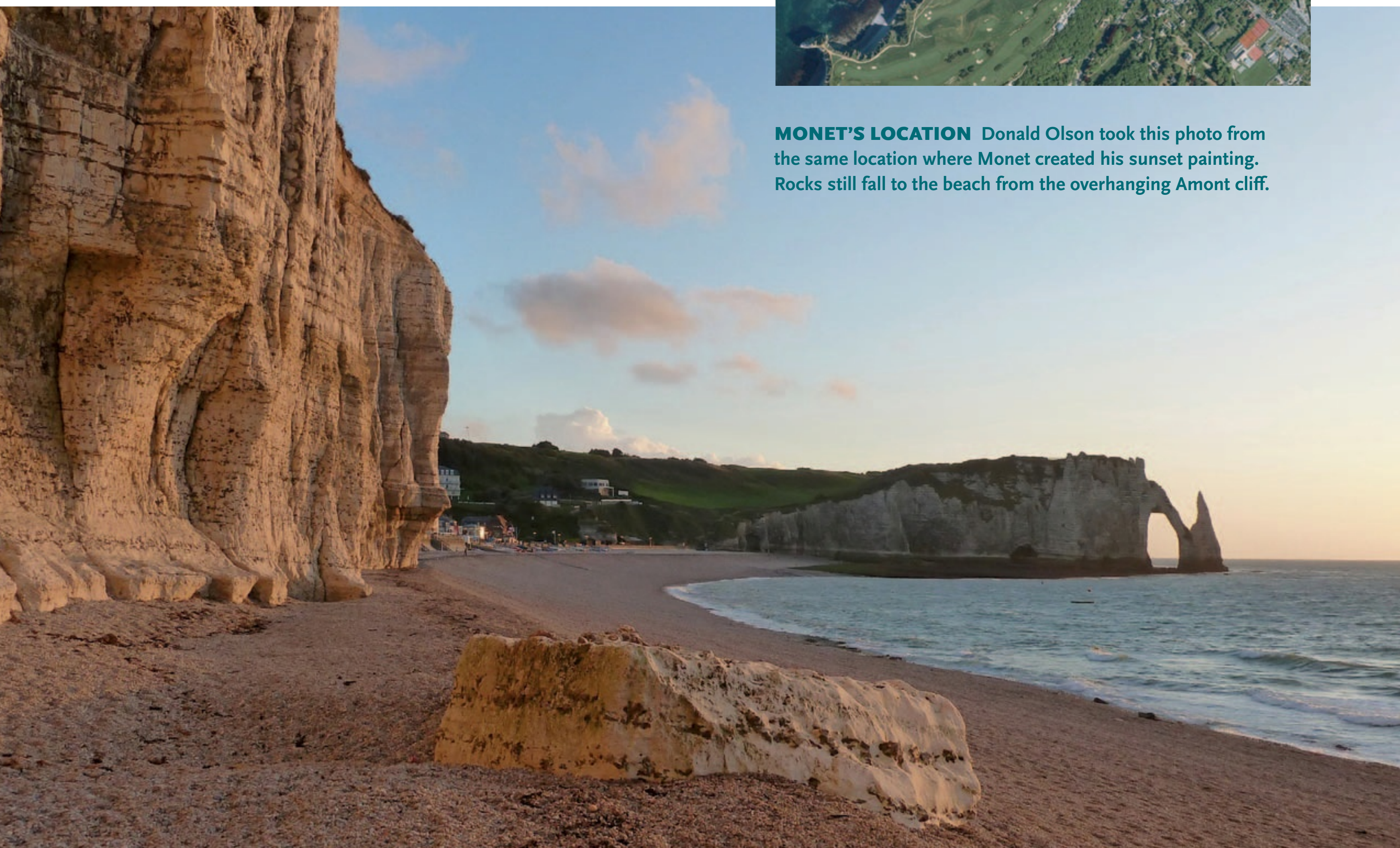


IMAGE: GOOGLE EARTH / CNES / SPOT / DIGITAL GLOBE / IGN-FRANCE
MAP: S&T: LEAH TISCIONE

ÉTRETAT ***Right:*** **The town of Étretat lies near the center of a crescent-shaped bay. A cliff known as the Falaise d'Amont forms the northeast half of the crescent and includes a small arch called the Porte d'Amont (Upstream Portal). To the southwest of the town is the cliff known as the Falaise d'Aval, with the Porte d'Aval. Beyond this arch stands the Needle. The red dot marks Monet's location according to Robert Herbert, who places the artist only "a few yards" from the seaward end of the Amont promontory. The yellow dot marks Monet's actual location as determined by the Texas State group. This correct location is about 425 yards (390 meters) from the Porte d'Amont.**



MONET'S LOCATION Donald Olson took this photo from the same location where Monet created his sunset painting. Rocks still fall to the beach from the overhanging Amont cliff.

In his 1995 biography *Claude Monet*, scholar Charles Stuckey, discussing the paintings from Normandy, pointed out the importance of tides: "For these coast-scapes, Monet must synchronize his work sessions with both solar and tidal clocks."

The sunset painting shows water along the base of the Aval cliff and water passing through the Porte d'Aval. The time depicted by Monet therefore could not have been near a low tide because large areas of rock and seabed on the Aval side of the bay become dry and completely exposed. During several periods of rising tides, our Texas State group watched the water rise, cover the beach near the Porte d'Aval, and begin to pass through the arch. We established exactly how high the tide had to rise to match Monet's sunset painting.

We also collected Normandy meteorological observations for February 1883 from three sources: daily weather maps and remarks in the Times of London, a volume titled *Bulletin International du Bureau Central Météorologique de France*, and the letters written by Monet, in which the artist discussed how rainfall and sky conditions affected his work.

We could rule out February 3rd for the sunset painting because a letter by Monet makes it clear that on this day he was not on the Amont beach to the northeast of Étretat. Instead, he had walked out for the first time to the Jambourg beach, with spectacular terrain to the southwest of town.

Our group could also exclude February 4th because Monet complained in a letter that his entire day of work was lost as he entertained his visiting brother Léon. That evening, the artist wrote in a letter to Alice Hoschedé: "I promise myself a hard day of work tomorrow."

February 5th, the best-fit date from our astronomical analysis, also has all the other conditions for a perfect match to the sunset canvas. Monet wrote to his art dealer, A. P. Durand-Ruel, that he was optimistic about his progress: "I work a lot. The weather is happily becoming quite beautiful." A meteorological observer on the Normandy coast near Étretat reported good weather with a few clouds at sunset, matching the sky painted by Monet. The calculated low tide on February 5th occurred about 2¼ hours before sunset, and shortly before sunset the tide had already risen enough to cover the rocks and seabed near Porte d'Aval, just as seen in Monet's sunset painting.

We can rule out February 6th because the tide reached its lowest level only 1¼ hours before sunset. The rocks under the Porte d'Aval would still have been exposed near sunset, in conflict with the appearance of the sea level in Monet's painting.

We can reject February 7th for reasons of both weather and tides. Low tide occurred only a half hour before sunset, with the tide level near sunset even lower than on the previous day. Moreover, the weather had taken a turn for the worse, with heavy clouds and rain.

MOONSET Russell Doescher captured the waxing crescent Moon near the Porte d'Aval and the Needle in August 2012. For the benefit of tourists, the town of Étretat directs artificial lighting at the cliff, arch, and Needle in the evenings after the sunlight fades. Monet's location for his sunset painting lies about 100 yards (90 meters) to the northeast of where this photo was taken.

Our analysis thus determines that the only date matching the sunset painting is February 5, 1883.

Height of the Needle

To obtain a precise clock time on this date, we wanted to determine the Sun's angular height above the horizon. As seen from Monet's location, the actual height of the Needle rock formation in feet (or meters) translates into an angular height that in turn establishes an angular scale for the Sun's altitude.

In his 1994 book, Robert Herbert described the Needle as "a towering pyramid some 225 feet high." His source may have been a 19th-century guidebook published by Adolphe Joanne or Karl Baedeker, who gave the height of the Needle as either 225 feet or 230 feet in various editions. Modern European guidebooks still give the height of the Étretat Needle as 70 meters (230 feet).

This consensus may seem impressive. But, in fact, all of the succeeding descriptions may have originated in one early source, perhaps an early Joanne volume. If the height in this guide is wrong, then all of the following authors are likewise incorrect.

There's an interesting complication: the amount of the Needle that is visible above the waves varies tremendously

NORMANDY SUNSET Local amateur astronomer Jean Langlois took this photograph on February 3, 2012, a near-match to Monet's sunset painting. A few minutes later, the Sun dropped to an altitude corresponding better to Monet's canvas, but thick clouds near the horizon blocked the view.

as the tide rises and falls. The tide range in Étretat can reach 28 feet, with that much more or less of the Needle exposed, depending on the state of the tide.

We determined the height of the Needle with a laser rangefinder to measure distances and a laser inclinometer and sextant to measure angles. We carefully noted the tide level at the moment when each measurement was made. Our results established that the values near 230 feet for the Needle's height are clearly incorrect. We observed that, at the time of the lowest tides, the top of the Needle stands about 179 feet above the exposed base. At the highest tides, only 151 feet of the Needle remain visible above the waves.

To see more images related to this article, visit skypub.com/Monet.

An intermediate case prevailed as Monet watched the orange disk of the Sun sink toward the horizon. For a time shortly before sunset on February 5, 1883, we calculate that the top of the Needle stood 167 feet above the level of the sea.

In the 1996 book *Monet, Catalogue Raisonné*, art historian Daniel Wildenstein suggests that the Needle's height has changed significantly since Monet's time and claims that "the tip of the Needle, which has suffered from erosion, is less clearly seen above the Porte d'Aval."

To check how much erosion may have occurred, we studied dozens of century-old photographic postcards, which are easy to find because Étretat has been such a popular resort. We selected three of the clearest views of the Needle and found the precise spots where the postcard photographers had stood. Using *Photoshop* to overlay our modern digital photographs on top of the vintage views, we could trace exactly the same geological layers as dark and light bands all the way to the top of the Needle. Somewhat surprisingly, we can be certain that the Needle's height has experienced negligible erosion during the past century.

Moment of Inspiration

From Monet's location on the Amont beach, the top of the Needle extends about 2.6° above the horizon. As painted by Monet, the Sun stood about 0.9° above the horizon. Our astronomical analysis, confirmed by meteorological observations, tide calculations, topographic data, and comments in Monet's letters, yields the date and precise time for the moment depicted in *Étretat: Sunset*: February 5, 1883, at 4:53 p.m. local mean time.

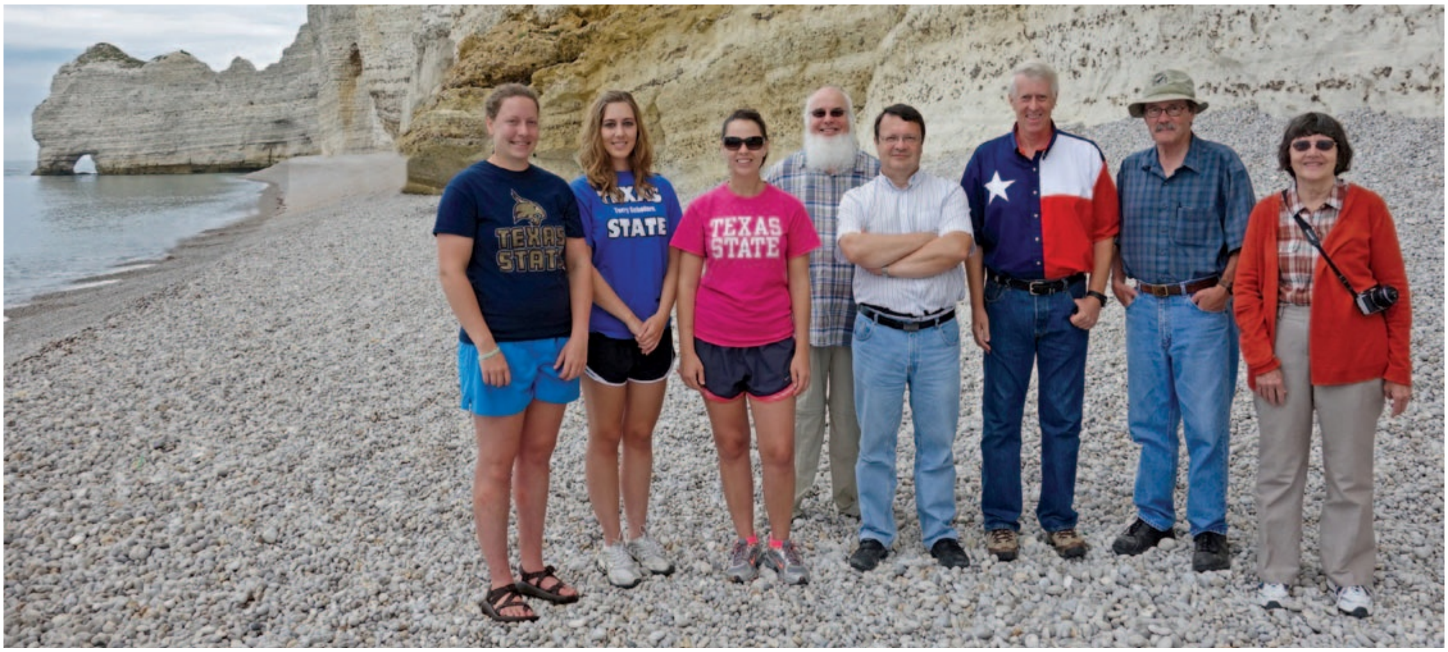
The Sun's seasonal path has not significantly changed since the 1800s. Visitors to Étretat can check our results on any February 5th by walking out along the Amont beach about 100 yards beyond the northeast end of the modern Étretat terrace. If the weather cooperates, the Sun will sink to the horizon just north of (to the right of) the Needle, repeating the scene captured by Claude Monet in his beautiful *Étretat: Sunset*. ✦

__Don Olson__ and __Russell Doescher__ teach in the Department of Physics at Texas State University, where __Laura Bright__, __Hannah Reynolds__, and __Ava Pope__ were undergraduate students in the honors course "Astronomy in Art, History, and Literature." The Texas State group's research projects, many previously published in S&T, *have been collected in Olson's new book,* Celestial Sleuth *(Springer Praxis, 2014).*

COLLECTION OF DONALD OLSON

AVA POPE

THE NEEDLE **A comparison of a postcard from about 1905 to a 2012 photo shows that the Needle's height has not eroded much over the past century. The Fort de Frefosse castle in the postcard was constructed on the cliff around 1890 and then demolished in 1911. The distant Porte d'Amont is visible through the Porte d'Aval.**



RUSSELL DOESCHER

CELESTIAL SLEUTHS **Left to right: Ava Pope, Laura Bright, Hannah Reynolds, Russell Doescher, Jean Langlois, Donald Olson, Roger Sinnott, and Marilynn Olson stand on the Amont beach near Monet's location for the sunset and daytime paintings. The forward point of the Amont promontory and the small Porte d'Amont arch are visible in the distance, about 425 yards away.**

In This Section

Additional Observing Articles:

This false-color infrared image shows newborn stars in and near the Orion Nebula. North is to the left.

PHOTOGRAPH: NASA / JPL-CALTECH / JOHN R. STAUFFER

FEBRUARY 2014

Jan 18 – Feb 2 **EARLY EVENING:** The zodiacal light shows very well from dark locations at mid-northern latitudes. Look west starting about 80 minutes after sunset for a huge, tall, left-sloping pyramid of light.

Feb 1 **DUSK:** Mercury shines below the thin crescent Moon low in the west 45 minutes after sunset, as shown on page 48.

10 **EVENING:** Jupiter shines left of the Moon.

14 **EVENING:** Algol is at minimum brightness for roughly two hours centered on 8:55 p.m. PST (11:55 p.m. EST); see page 51.

Feb 16 – Mar 2 **EARLY EVENING:** The zodiacal light is again on display as described above.

17 **EVENING:** Algol is at minimum brightness for roughly two hours centered on 8:44 p.m. EST.

19 **DAWN:** Spica shines close to the left of the Moon, with much brighter Mars farther above Spica.

22 **DAWN:** The Moon shines left of Saturn in the Americas. It occults Saturn around midnight on the 21st in Madagascar and during daylight on the 22nd in Australia and New Zealand.

26 **DAWN:** The thin crescent Moon forms a spectacular pair with Venus. It occults Venus before or after dawn in parts of Africa and southern Asia.

27 **DAWN:** Binoculars should show Mercury lower left of the superthin crescent Moon very low in the east-southeast 30 minutes before sunrise. Look for them to the far lower left of Venus.

Planet Visibility

SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH

◀SUNSET — MIDNIGHT — SUNRISE▶

Planet	Visibility
Mercury	SW — Visible January 17 through February 7
Venus	SE
Mars	E — S — SW
Jupiter	E — S — NW
Saturn	E — S

Moon Phases

First Qtr February 6 2:22 p.m. EST — Full February 14 6:53 p.m. EST

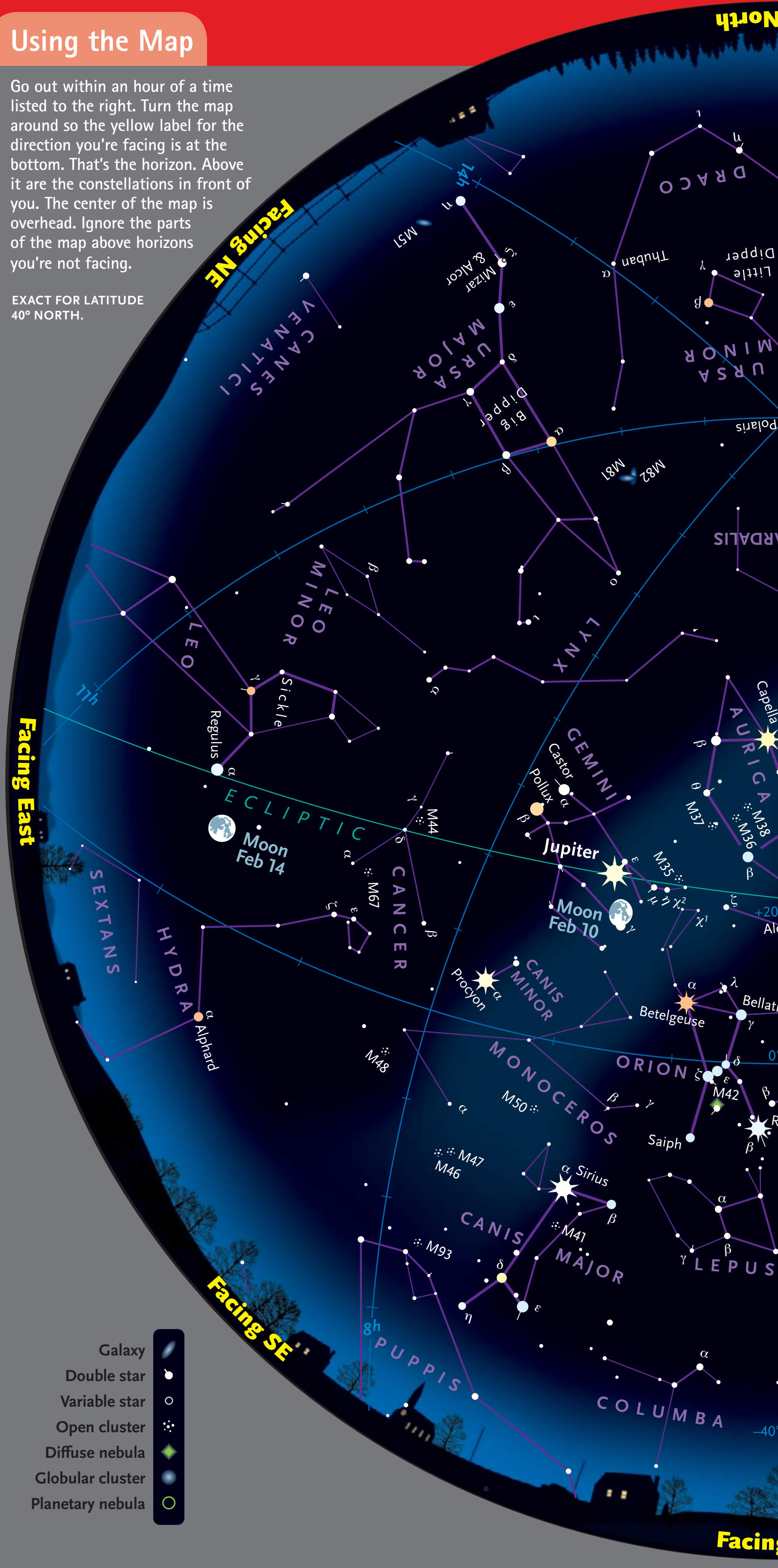
Last Qtr February 22 12:15 p.m. EST

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

Using the Map

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

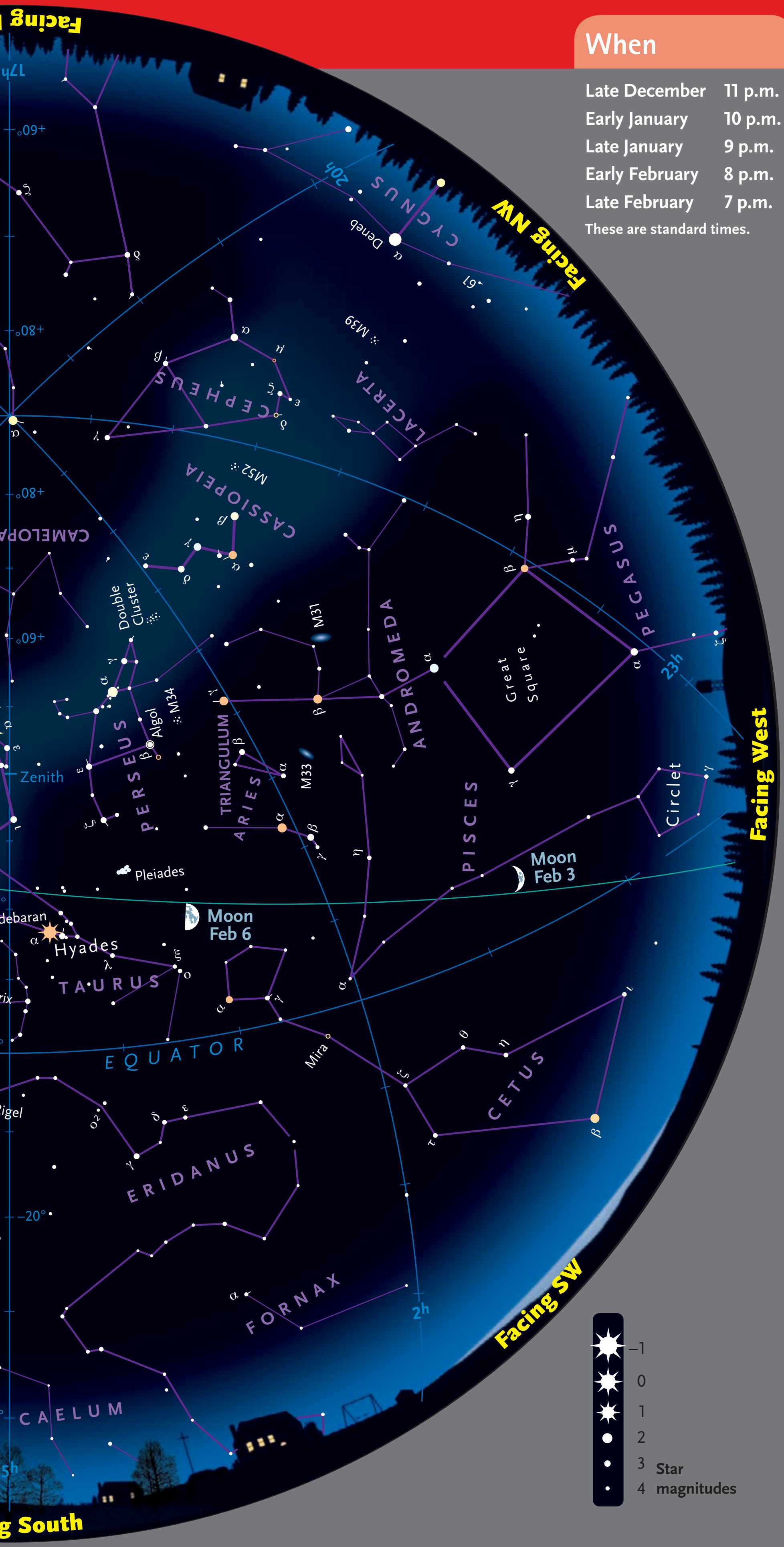
EXACT FOR LATITUDE 40° NORTH.



When

Late 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.



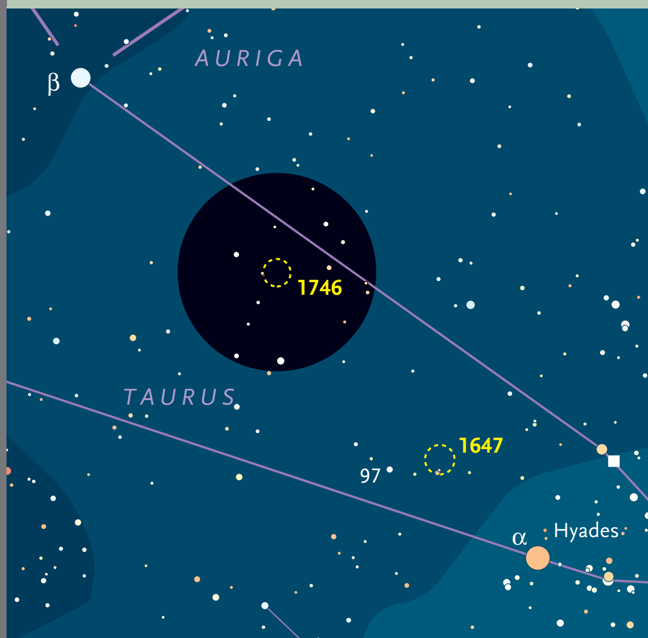
Gary Seronik
Binocular Highlight

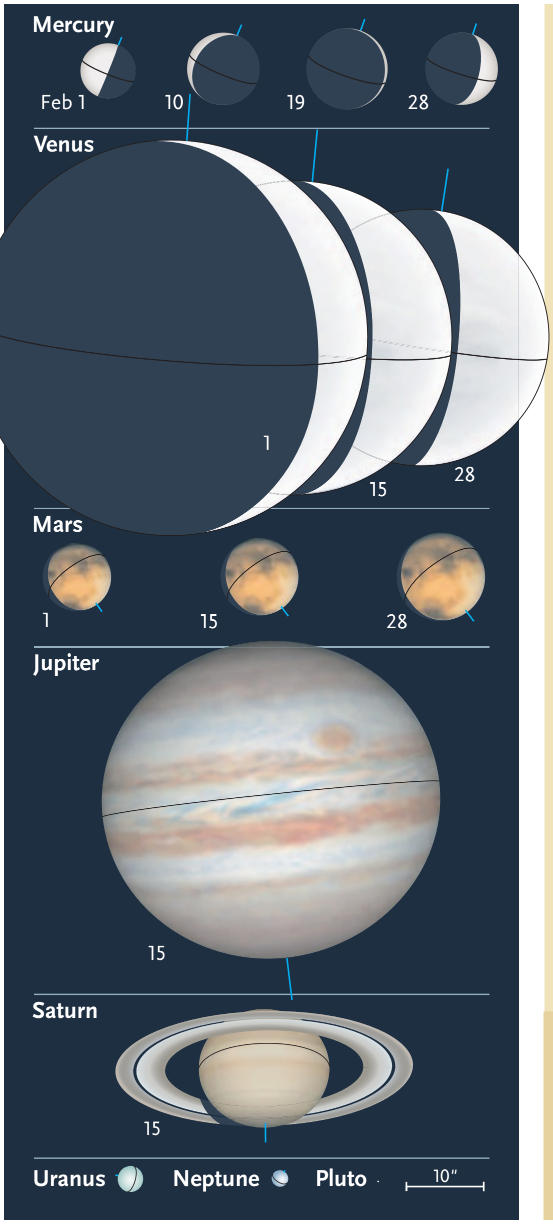
Minor Taurus Treasures

When it comes to Taurus binocular highlights, the object that springs immediately to mind is M45, the Pleiades star cluster. Some will also throw in the Hyades, and a few experienced observers might add M1, the Crab Nebula. But the Taurus list is actually a little longer than that. Two minor treasures between the horns of the celestial Bull also merit attention: **NGC 1647** and **NGC 1746**.

Both of these open clusters lie along a line connecting Aldebaran (α Tauri) to Elnath (β Tauri). NGC 1647 is the nicer of the two. This 6.4-magnitude object is situated at the western end of a curving row of 6th-magnitude stars that includes 5.1-magnitude 97 Tauri as the middle of the arc. The cluster itself has a small core of a half-dozen stars, surrounded by a scattering of fainter ones that pop in and out of view. To my eye, NGC 1647 looks like a little crab, with the central clump forming the crustacean's body and the faint outer stars providing the spidery legs. The little crab cluster shows well in my 10×50 binoculars under reasonably dark skies.

Even though it's listed at magnitude 6.1, neighboring NGC 1746 is a more challenging find. The difficulty lies in the fact that it's quite large and sparse. In my 10×30 image-stabilized binoculars, I can see eight or ten individual stars with plenty of space between them. The brightest stars form a ragged letter C, with a few additional glints filling in the space between the C's tips. Although it's not the most spectacular cluster in the region, it does demonstrate one of the great strengths of binoculars: gloriously wide fields of view. In just about any telescope, the cluster simply dissolves into a scattering of random field stars. ✦



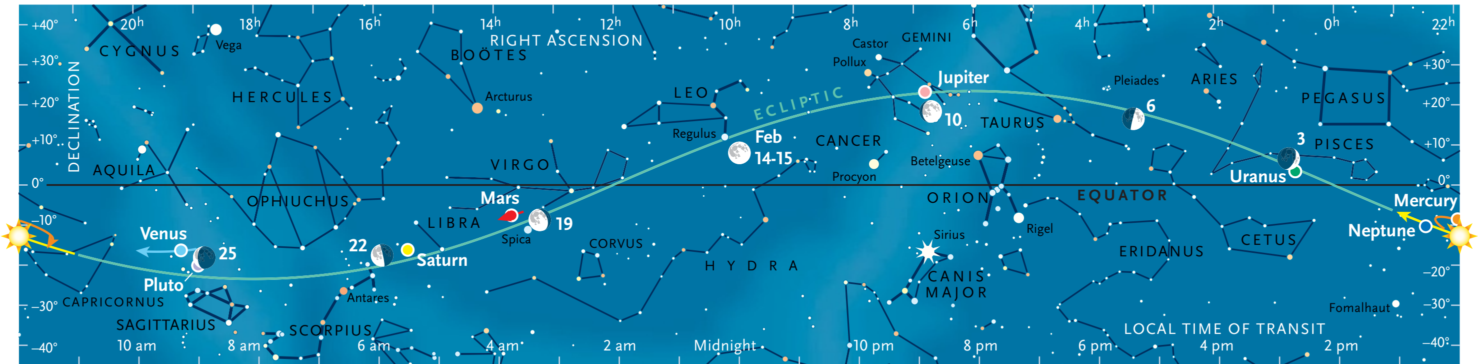


Sun and Planets, February 2014

	February	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$20^h\ 57.2^m$	–17° 14′	—	–26.8	32′ 28″	—	0.985
	28	$22^h\ 42.8^m$	–8° 09′	—	–26.8	32′ 18″	—	0.991
Mercury	1	$22^h\ 08.5^m$	–11° 01′	18° Ev	–0.6	7.1″	51%	0.944
	10	$22^h\ 12.9^m$	–8° 00′	12° Ev	+2.0	9.4″	11%	0.718
	19	$21^h\ 37.8^m$	–10° 18′	8° Mo	+3.9	10.5″	3%	0.641
	28	$21^h\ 19.1^m$	–13° 29′	21° Mo	+0.9	9.4″	25%	0.718
Venus	1	$18^h\ 55.2^m$	–15° 52′	29° Mo	–4.8	51.1″	13%	0.326
	10	$19^h\ 01.9^m$	–16° 14′	37° Mo	–4.9	44.1″	21%	0.378
	19	$19^h\ 19.5^m$	–16° 35′	41° Mo	–4.8	38.1″	29%	0.438
	28	$19^h\ 44.9^m$	–16° 39′	44° Mo	–4.8	33.1″	36%	0.503
Mars	1	$13^h\ 28.7^m$	–6° 34′	109° Mo	+0.2	8.9″	91%	1.057
	15	$13^h\ 40.7^m$	–7° 34′	120° Mo	–0.1	10.1″	93%	0.926
	28	$13^h\ 45.5^m$	–7° 53′	132° Mo	–0.4	11.5″	95%	0.816
Jupiter	1	$6^h\ 52.3^m$	+23° 05′	150° Ev	–2.6	45.6″	100%	4.326
	28	$6^h\ 44.9^m$	+23° 16′	121° Ev	–2.4	42.6″	99%	4.631
Saturn	1	$15^h\ 22.3^m$	–16° 11′	79° Mo	+0.5	16.6″	100%	10.020
	28	$15^h\ 25.3^m$	–16° 17′	106° Mo	+0.4	17.4″	100%	9.575
Uranus	15	$0^h\ 37.1^m$	+3° 17′	44° Ev	+5.9	3.4″	100%	20.732
Neptune	15	$22^h\ 26.5^m$	–10° 29′	9° Ev	+8.0	2.2″	100%	30.954
Pluto	15	$18^h\ 53.4^m$	–20° 10′	44° Mo	+14.2	0.1″	100%	33.307

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

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

Fred Schaaf

Out of Orion

The mighty constellation is the heart of the winter sky.

We were moving out, boy, with the three hundred suns of the Pleiades glittering like a puddle of jeweled milk on our left, and all blackness wrapped around our right. The ship was me; I was the ship.

— Samuel R. Delany, *Nova*

In Delany's dazzling 1968 novel, the character quoted above was plugged into his spaceship so that he could pilot it directly with his central nervous system. That's the literal meaning of "The ship was me; I was the ship."

But observational astronomers could figuratively say the same about their telescopes. We live through these wondrous instruments until we become inseparable from them. Let's take a telescopic journey outward through Orion, and then perhaps you will be able to say with conviction: "The telescope was me; I was the telescope."

The Huygenian Region. We will begin our journey in the very center of centers in Orion: the intense bright core of the Great Orion Nebula (Messier 42). It's named the Huygenian Region, after its early observer Christiaan Huygens. It contains the knot of four bright stars (and at least four lesser ones) called the Trapezium. At high enough magnification, the region shows a texture that was perhaps best described by John Herschel in 1820: "A curdling liquid or surface strewn with flocks of wool — or like the breaking up of a mackerel sky."

AKIRA FUJII

The green glow here is so strong that when I bought one of the early commercial 13.1-inch Dobsonians more than 30 years ago, I was astounded to see the light from the eyepiece coloring my hand green. Directly neighboring the Huygenian Region is the dark indentation that the 19th-century observer Admiral W. H. Smyth famously called "the fish's mouth" and, just beyond, the seemingly separate glow of the comma-shaped nebula M43.

The Orion Nebula as a whole. At lower magnification, M42 spreads long eagle wings from the Huygenian region, and some of us begin to see a pinkish — or could it be a combination purplish and very short-wavelength violet? — tinge on those wings. The entire nebula has also been compared to a degree-wide blossom. One could easily observe its translucent details for an hour or more at a time on every winter night.

The glorious Sword and Belt. Expanding our view outward from M42 we encounter a wide wonderland that includes the peerless asterisms of Orion's Belt and Sword. More nebulae, both bright and dark; star clusters; double and multiple stars galore; and individual (mostly frosty blue) stars sprinkled burning everywhere. The richness and variety is staggering. Anywhere else in the heavens NGC 1977 would itself be a major showpiece nebula, but here it's often overlooked. The 4.5-magnitude cluster NGC 1981 seems to me to have the right shape and position to form the handle of the Sword. Multiple stars such as Iota and Sigma Orionis are amazing. The challenging, tiny, dark Horsehead Nebula contrasts with the large, rather bright — yet darkness-fretted — Flame Nebula.

Orion's frame. The rectangle formed by Orion's shoulders and knees includes Rigel and its white-dwarf companion Rigel B, the warm-up for seeking Sirius B (*S&T:* October 2013, page 30). It encloses wonders like the shining nebula patches of M78, which lie near the vertex of a right triangle with the Belt, and huge Barnard's Loop, a super challenge for the nebula-filter-aided naked eye.

Orion's outliers. There are dozens of major wonders in the Milky Way constellations that surround Orion: Canis Major, Monoceros, Gemini, Auriga, and Taurus (see page 28). To consider them merely as outliers of Orion shows how magnificent Orion's own splendors are. But there's one great outlier that fittingly leads these constellations, Orion's whole vast battalion of brightness, across the sky as vanguard. It's the subject of our opening quotation: the Pleiades. ✦

The Planets of War and Love

Mars brightens rapidly, and Venus reaches maximum brilliance.

Mercury glimmers low in the west-southwest at dusk during the first week of February. Jupiter appears ever higher in the east to southeast at nightfall as the month progresses. Jupiter culminates (reaches its highest in the south) around mid-evening — shortly before brightening Mars rises.

Saturn comes up around midnight and hangs highest in the south in early dawn. Blazingly bright Venus rises about 2 hours before the Sun, around the time when Mars shines highest.

DUSK

Mercury has a fine evening apparition in the last week of January and first few days of February. It's at greatest evening elongation on January 31st (18° east of the Sun), then falls and fades rapidly after February 4th. The swift planet shines at magnitude –0.5 and is half lit on February 1st, when it's still 8° high 45 minutes after sunset as seen from 40° north latitude. But by February 8th Mercury is 4° lower, 15% sunlit, and just one-sixth as bright (magnitude +1.5), making it challenging even with binoculars.

Mercury passes through inferior conjunction on February 15th, and it may be visible before sunrise in binoculars by the end of the month.

Uranus can still be glimpsed at the end of evening twilight, though it's getting low (see **skypub.com/urnep** for a finder chart). **Neptune** goes through conjunction with the Sun on February 23rd, so it's unviewable throughout the month.

EVENING AND NIGHT

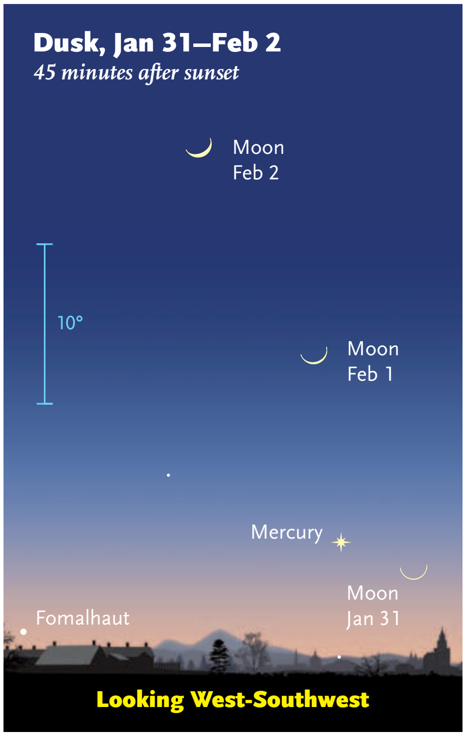
Jupiter was at opposition on January 5th, so February finds it already well up in the east or southeast as the sky darkens. It shines in Gemini, dimming a bit from –2.6 to –2.4 in February as it slowly retrogrades (moves westward relative to the background stars). The big planet is high for most of the night as seen from mid-northern latitudes; it's highest around 10 p.m. as February begins and 8 p.m. as the month ends. Its diameter shrinks from 46″ to 42″. But Jupiter always appears large enough through a medium-sized telescope to see great detail in its clouds if the air is sufficiently steady.

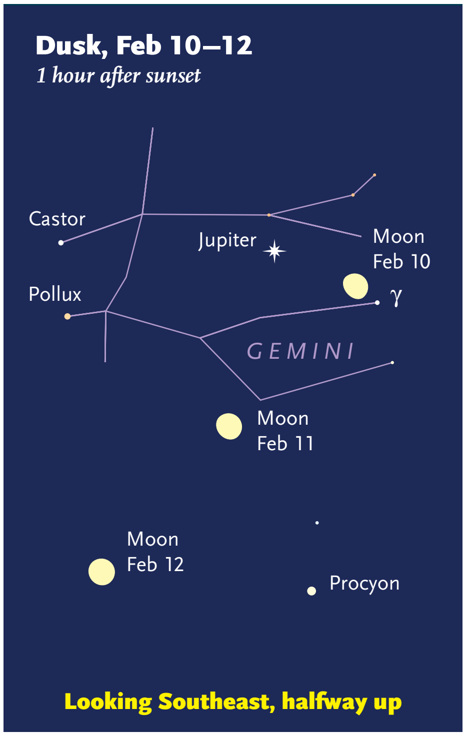
Asteroid 2 Pallas is south of Alphard (α Hydrae) in February, shining at magnitude 7.0 in the second half of the month. It reaches opposition on February 22nd. The March issue will contain a finder chart.

LATE NIGHT TO DAWN

Mars rises around 11 p.m. as February opens and around 9:30 as February closes. It's highest an hour or two before dawn. The orange-yellow planet brightens rapidly during the month, from magnitude +0.2 to –0.4. Mars ends February significantly brighter than Arcturus, which shines far to the planet's upper left. Mars is moving slowly eastward, about 5° to 6° northeast of fainter Spica.

In telescopes Mars grows from 9″ to 11½″ wide during February, big enough for telescopes to reveal glimpses of its surface features. The planet's northern hemisphere is at its summer solstice on February 15th, so the north polar ice cap



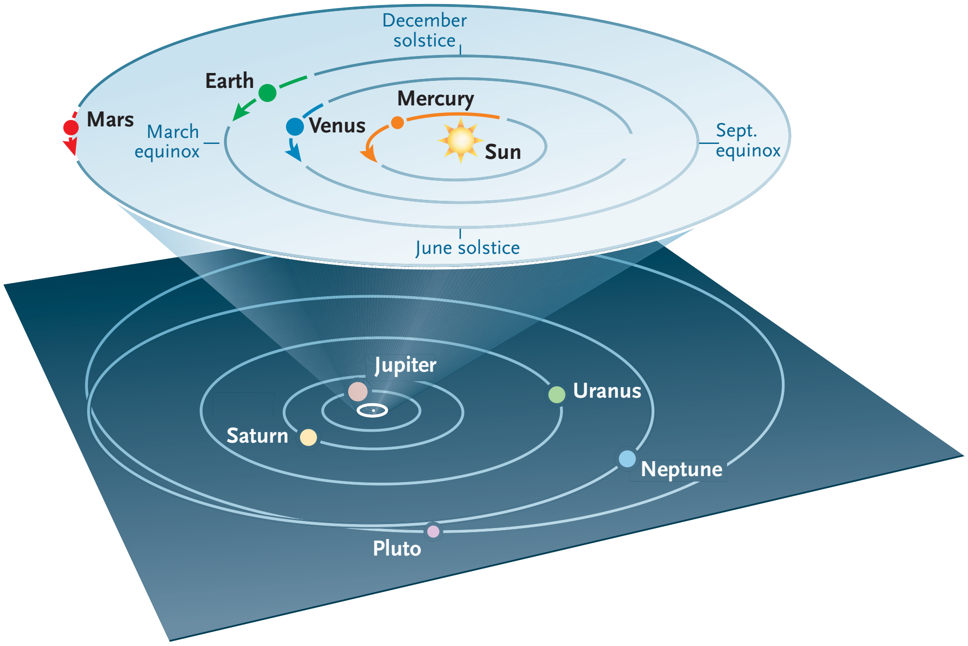


These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west); European observers should move each Moon symbol a quarter of the way toward the one for the previous date. In the Far East, move the Moon halfway. The blue 10° scale bar is about the width of your fist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

Fred Schaaf

ORBITS OF THE PLANETS

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



may be too small to detect. Mars will reach 15″ around its April 8th opposition.

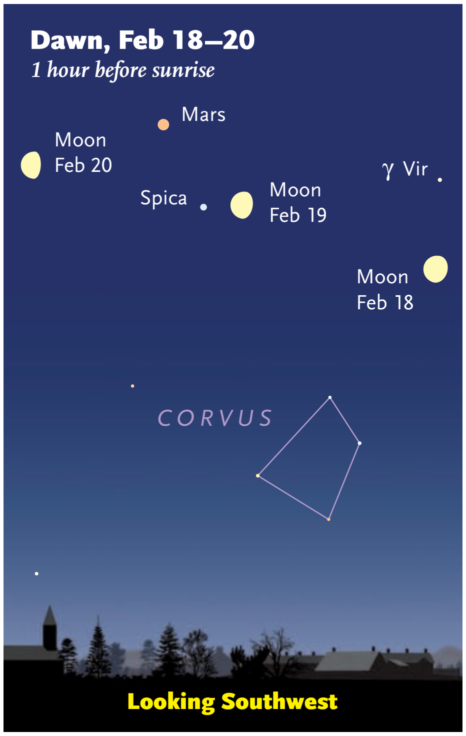
Saturn rises golden in Libra around 1:30 a.m. as February begins and before midnight for many observers as the month ends. The planet transits the meridian during morning twilight. It reaches western quadrature (90° west of the Sun) on February 11th, so this is the month when the shadow of Saturn's globe on its rings is most prominent. The glorious rings are tilted a temporary maximum of almost 23° from edge-on.

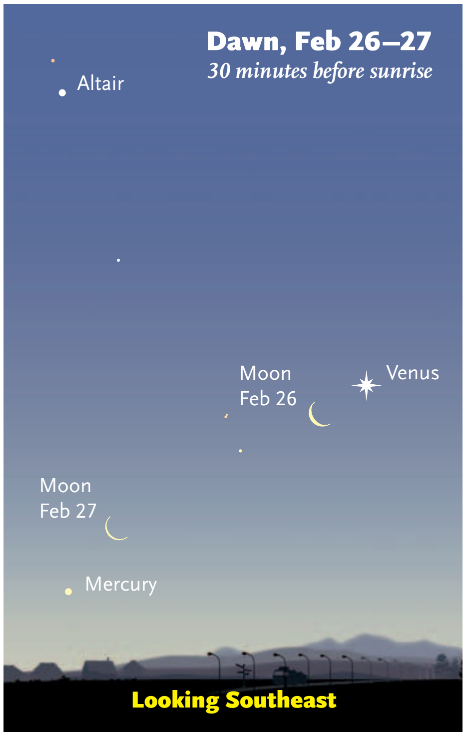
DAWN

Venus dazzles at its maximum magnitude of –4.9 in mid-February. Unfortunately, this brightest of worlds comes up only 2 to 2½ hours before the Sun for skywatchers at mid-northern latitudes. Venus's elongation from the Sun grows, but at month's end observers at 40° north latitude still see it only 18° high in the southeast 30 minutes before sunrise.

During February, Venus's crescent thickens from 13% to 36% sunlit, and the distance from cusp to cusp decreases from 51″ to 33″. Venus displays its greatest illuminated extent (number of square arcseconds lit) at mid-month.

Mercury is a difficult catch even with optical aid on February 27th and 28th; it's dim at magnitude +1.0 to +0.8 and also very low. Look far to Venus's lower left.





MOON PASSAGES

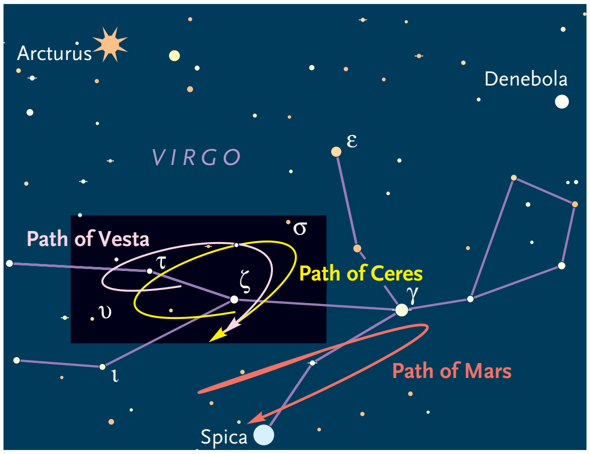
The waxing gibbous **Moon** is to the right or lower right of Jupiter on the evening of February 10th in North America. The full Moon is to the right of Regulus at nightfall on February 14th. Before dawn on February 19th, the waning gibbous Moon is quite close to the right of Spica, with Mars not far to their upper left.

At dawn on February 21st the Moon is well to the right of Saturn in the Americas. The Moon occults Saturn around midnight in Madagascar and during daylight on the 22nd in Australia and New Zealand. On February 26th, the waning crescent Moon is just a few degrees lower left of Venus, a beautiful pairing. The Moon occults Venus before or shortly after sunrise in parts of Africa, and during daylight in southern Asia. On February 27th, the lunar crescent is several degrees upper right of difficult Mercury. ✦

Ceres & Vesta Travel in Tandem

A dwarf planet and a protoplanet are flying just a short star-hop apart.

The biggest asteroid and the brightest one — 1 Ceres and 4 Vesta, respectively — go looping nearly in parallel across Virgo this winter, spring, and summer. Between them, by no coincidence, will be an unseen third body: NASA's Dawn spacecraft. It's on its way from a successful year of orbiting and studying Vesta in 2011–12 to a rendezvous with Ceres in February 2015. Once there it will brake into orbit around Ceres and take up permanent residence.

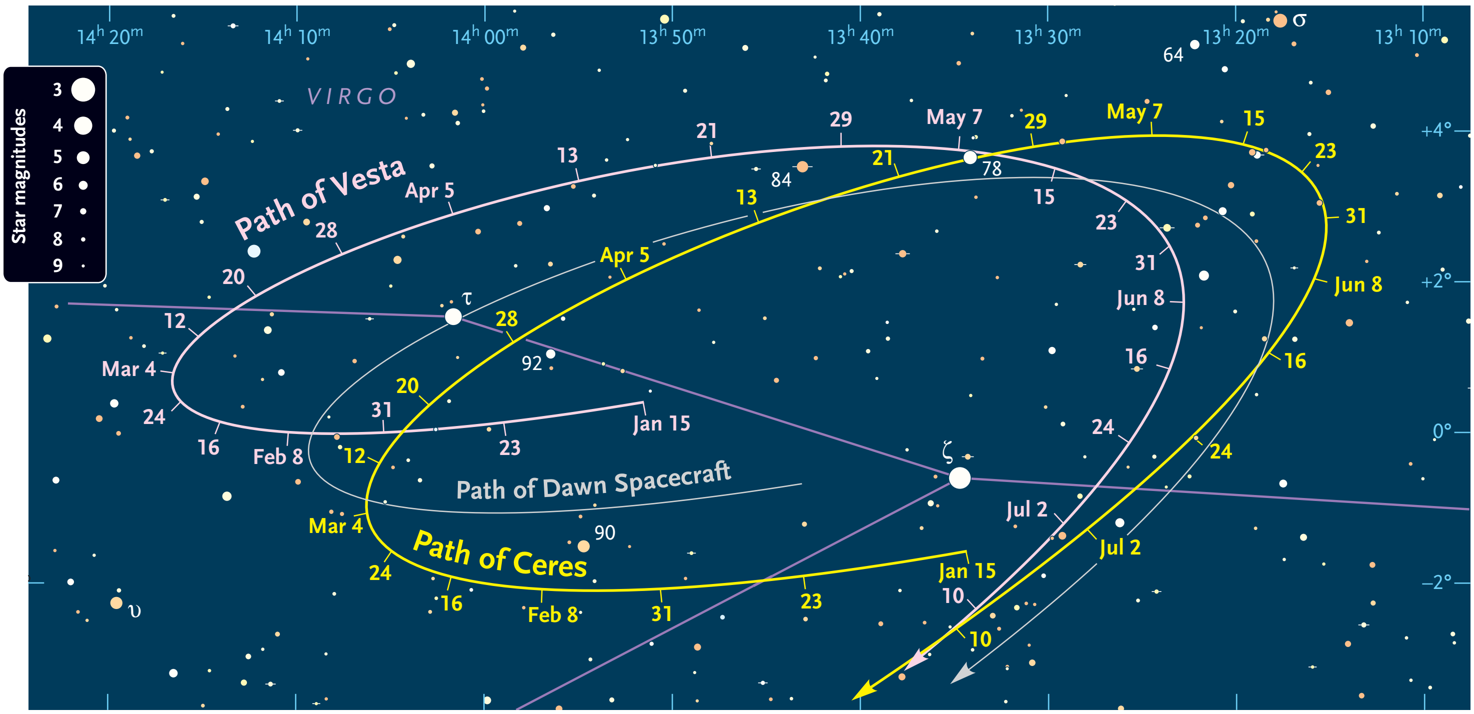


Although both bodies are classified as asteroids, each qualifies as something more, making them unusually interesting targets for Dawn to reconnoiter up close. At Vesta, Dawn surprised astronomers by revealing that despite Vesta's small size (356 × 346 × 277 miles, or 573 × 557 × 446 km), it could qualify as a "planet" in one sense. Like Earth and company, it completely melted early on to become *differentiated:* iron sank to the center, light crustal rock floated to the top, and a middle-density mantle remains in between. Accordingly, the term "planetoid" is being applied to Vesta.

Ceres is nearly twice as large at 585 miles (940 km) in mean diameter, and its self-gravity is strong enough to have pulled it into a rounder shape as revealed by Hubble images. That makes Ceres a "dwarf planet," like Pluto, by the vague criterion of roundness set by the International Astronomical Union in 2006. How round is round? Dawn will find out. Its high-resolution imagery should also tell what's going on with Ceres's tantalizingly varied surface composition.

With Your Own Eyes

The two asteroids loop near Spica and Mars this year. In early winter they're in the early-morning sky, still months from their April opposition. The table at right lists their magnitudes and separation on the first of each month until they ride off into the sunset this fall.



You might think that their high point of the year would be around opposition, when they'll be brightest and easy to see in the same binocular field of view. But look at their separations. After holding 2° or 3° apart for three months, they'll pass much closer together in the same telescopic field in early July. They'll appear closest on July 5th, only 10 arcminutes apart. They'll remain less than ½° apart from June 29th to July 12th. But their closeness is an illusion; they'll be at different distances, more than 40 million miles from each other.

The close-up chart shows stars to magnitude 9.0, more than enough for identifying Ceres and Vesta starting in January. Date ticks are plotted at 0:00 UT every 8 days for easy interpolation. Remember that in the time zones of the Americas, 0:00 UT comes early on the evening of the previous date. To see Virgo high in January and February you'll need to be out roughly a third of a day later, in early-morning hours.

Put a pencil dot on the track of each asteroid for the date and time you plan to look. On the map north is up, east is left. To see how big the star patterns will appear in your finderscope's field of view, use the degree scale along the right edge. Plan your star-hops accordingly.

Keep checking in on these two asteroids in the coming months, as Dawn leaves one farther behind and heads toward a new history-making encounter with the next.

Ceres & Vesta Paired

Date (0^h UT)	Ceres mag.	Vesta. mag.	Sep.
Jan. 1	8.6	7.7	5.1°
Feb. 1	8.2	7.2	4.1°
Mar. 1	7.8	6.6	3.2°
Apr. 1	7.1	5.9	2.4°
Apr. 14*	7.0	5.8	2.5°
May 1	7.2	6.0	2.5°
June 1	7.8	6.6	2.0°
July 1	8.4	7.1	0.4°
Aug. 1	8.8	7.4	2.1°
Sept. 1	9.0	7.7	5.0°

*Ceres is at opposition on April 15th, Vesta on April 13th.

Ceres and Vesta as imaged by the Hubble Space Telescope in ultraviolet and visible light, sized to the same physical scale.

NASA / ESA / LUCY MCFADDEN ET AL. / JOEL PARKER ET AL. (2)

Action at Jupiter

Jupiter was at opposition on January 5th, so during February it shrinks only slightly, from 46″ to 43″ in equatorial diameter, while shining very high in excellent telescopic view during evening.

- Any telescope shows Jupiter's four big moons. Binoculars usually show at least two or three, occasionally all four. Identify them with the diagram on the next page.
- The table on the next page lists all the February interactions between Jupiter, its shadow, and the satellites and their shadows. A 3-inch telescope is often enough for watching these events.
- Following are the times, in Universal Time, when Jupiter's Great Red Spot, now a relatively strong shade of orange, should cross Jupiter's central meridian. The dates, also given in UT, are in bold:

January 1, 8:25, 18:21; **2**, 4:16, 14:12; **3**, 0:07, 10:03, 19:58; **4**, 5:54, 15:50; **5**, 1:45, 11:41, 21:36; **6**, 7:32, 17:28; **7**, 3:23, 13:19, 23:14; **8**, 9:10, 19:06; **9**, 5:01, 14:57; **10**, 0:52, 10:48, 20:43; **11**, 6:39, 16:35; **12**, 2:30, 12:26, 22:21; **13**, 8:17, 18:13; **14**, 4:08, 14:04, 23:59; **15**, 9:55, 19:51; **16**, 5:46, 15:42; **17**, 1:37, 11:33, 21:29; **18**, 7:24, 17:20; **19**, 3:15, 13:11, 23:07; **20**, 9:02, 18:58; **21**, 4:54, 14:49; **22**, 0:45, 10:40, 20:36; **23**, 6:32, 16:27; **24**, 2:23, 12:18, 22:14; **25**, 8:10, 18:05; **26**, 4:01, 13:57, 23:52; **27**, 9:48, 19:43; **28**, 5:39, 15:35; **29**, 1:30, 11:26, 21:22; **30**, 7:17, 17:13; **31**, 3:08, 13:04, 23:00.

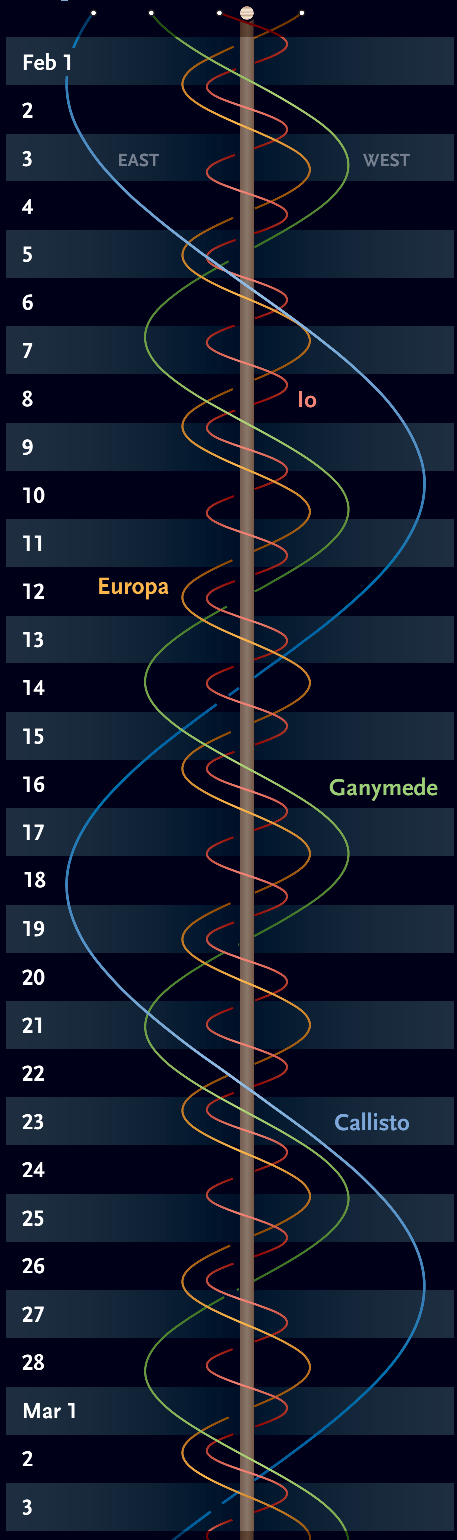
February 1, 8:57, 18:53; **2**, 4:48, 14:44; **3**, 0:40, 10:35, 20:31; **4**, 6:26, 16:22; **5**, 2:18, 12:13, 22:09; **6**, 8:05, 18:00; **7**, 3:56, 13:52, 23:47; **8**, 9:43, 19:39; **9**, 5:34, 15:30; **10**, 1:26, 11:21, 21:17; **11**, 7:13, 17:08; **12**, 3:04, 13:00, 22:55; **13**, 8:51, 18:47;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

These times assume that the spot is centered at about System II longitude 206°. If it's not following predictions, it will transit 1⅔ minutes early for every degree of longitude less, or 1⅔ minutes later for every degree more.

Minima of Algol

Jan.	UT	Feb.	UT
3	4:35	3	17:37
6	1:24	6	14:27
8	22:13	9	11:16
11	19:03	12	8:06
14	15:52	15	4:55
17	12:41	18	1:44
20	9:31	20	22:34
23	6:20	23	19:23
26	3:09	26	16:12
28	23:59		
31	20:48		

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.

The Phenomena of Jupiter's Moons, February 2014

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

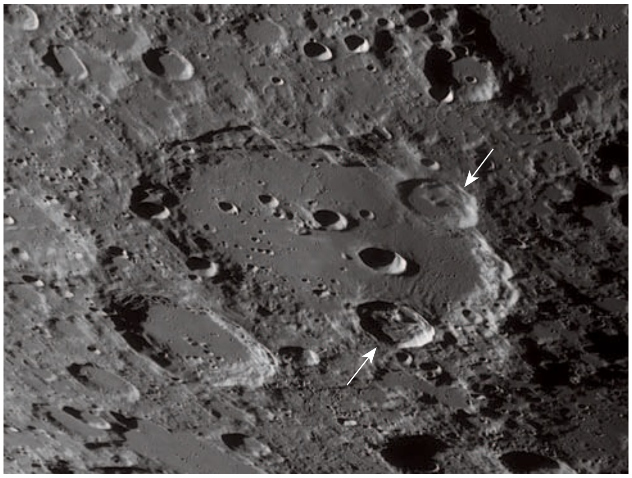
Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 5 hours ahead of Eastern Standard Time). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede, or **IV** Callisto. Next is the type of event: **Oc** for an occultation of the satellite behind Jupiter's limb, **Ec** for an eclipse by Jupiter's shadow, **Tr** for a transit across the planet's face, or **Sh** for the satellite casting its own shadow onto Jupiter. An occultation or eclipse begins when the satellite disappears **(D)** and ends when it reappears **(R)**. A transit or shadow passage begins at ingress **(I)** and ends at egress **(E)**. Each event is gradual, taking up to several minutes. Predictions courtesy IMCCE / Paris Observatory. ✦

Tilting Inward

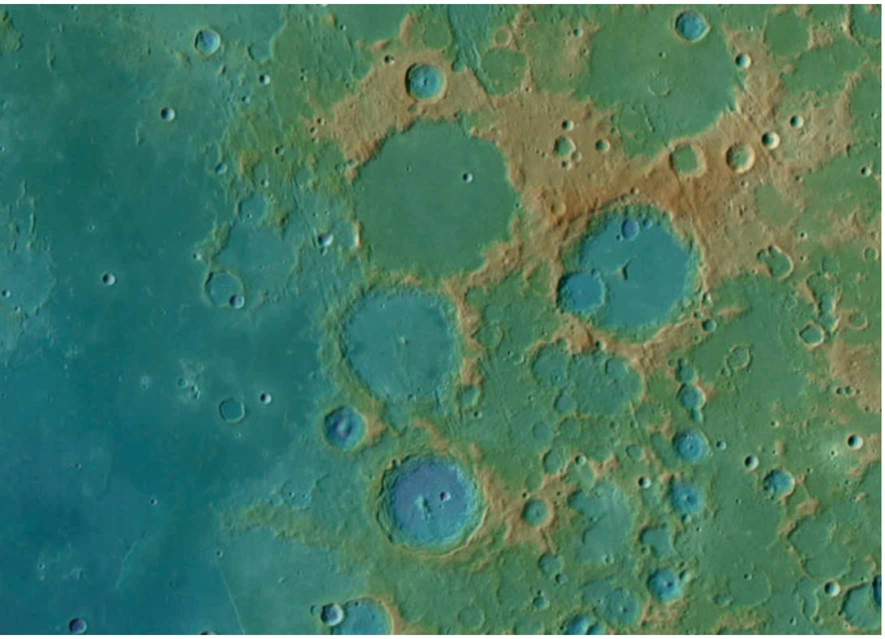
Track down craters that were influenced by their surrounding terrain.

Large craters often appear remarkably similar to one another, which is not surprising because they all formed by a massively energetic process. The explosion resulting from a half-kilometer-wide mountain colliding with the Moon at a velocity of 15 kilometers per second (33,600 mph) overcomes most idiosyncrasies of the lunar surface. The energy of the impact controls the diameter and depth of the resulting crater, as well as what it looks like. That's why Tycho, Copernicus, and various other large, complex craters look almost like identical twins.

But when you start looking closely, you'll notice slight differences due to the slope of the terrain that the craters formed on. To see how extreme slopes affect crater morphology, check out the two similar craters on the rim of **Clavius**. The southeast crater is **Rutherfurd**, and on the northeast rim is **Porter**. Using the altimetry tool of NASA's Lunar Reconnaissance Orbiter QuickMap (**http://target.lroc.asu.edu/q3**), Porter's northern rim was found to be about 3.5 km (2.2 miles) higher than its southern rim, which lies on the floor of Clavius. Similarly, Rutherfurd's southern rim is 2.5 km above its northern rim. Looking through a telescope, I could tell that the craters formed on slopes, but I didn't expect that the rim differences would be so extreme.


THIERRY LEGAULT

The low inner walls of the arrowed craters Porter (top) and Rutherfurd (bottom), which overlap the rim of Clavius, are visual clues that they both tip toward the large crater's center.


ACT-REACT-QUICKMAP

The large craters Ptolemaeus, Alphonsus, and Arzachel (center, top to bottom) are slightly higher on their east rims, as revealed in this color-coded topographic map from NASA's Lunar Reconnaissance Orbiter.

Using the QuickMap line tool and your own observations, it's now possible to recognize other differences in rim elevations due to more gentle slopes. For example, Mare Humorum is ringed with uneven-rimmed craters. The most conspicuous is the 110-km-wide crater **Gassendi**, whose northern rim is 2.4 km higher than its southern one, which faces the center of Humorum Basin. Visually, this is obvious because the east and west rim segments steadily decrease in elevation toward the mare, though the topographic extent would be unknown without QuickMap.

Three other craters along the Humorum impact basin's southern shore tilt toward the mare. The rims of **Doppelmayer** and **Lee** both decline in elevation from their southern highs and disappear totally within the mare to the north. **Vitello** is a younger crater with a rim that visually seems more even in elevation. But your eyes are deceiving you — QuickMap reveals that the rim nearest the mare is 900 meters lower than the southern rim.

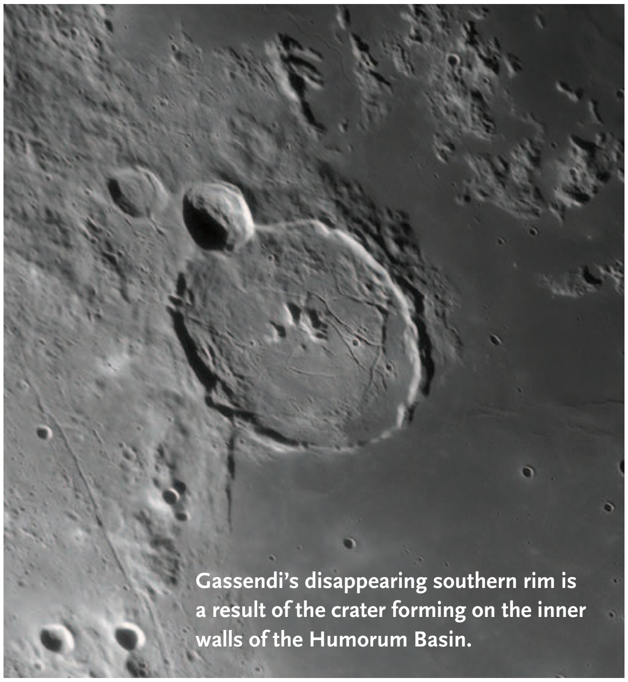
Looking closely at craters along the shores of other circular maria reveals the same phenomena. In the case of **Le Monnier**, it's obvious because the crater's rim is totally missing where it reaches Mare Serenitatis. Nearby **Posidonius** also tilts toward the mare, with its eastern side being 2.5 km higher — much like Gassendi — than the side facing the mare. The crater **Menelaus** is a

younger crater that formed right on Mare Serenitatis's southern boundary. And although its mare side is 2 km lower than the opposite rim, the elevation difference is completely undetectable at the eyepiece.

Fracastorius is another obviously tilted crater; it partly formed on the Nectaris Basin's inner ring and partly on the mare. Fracastorius actually formed after the basin but before the mare lavas flooded it: as you can see at the eyepiece, the lavas also flooded the lower half of the crater floor. In fact, the floor fractured, producing a delicate rille where the lower half of the crater tilted inward.

The Fracastorius fracture is a clue to how tilted craters formed on the margins of all basins. The impacts that excavated the craters occurred after the basins formed, otherwise the basins' formation would have obliterated any trace of them. Because the craters formed on terrain that sloped toward the basin centers, the craters were never flat — their entire structures tilted toward the basin's central low spot. The basin floors later sank, perhaps due to the weight of lava eruptions, further tilting the craters and enabling lava to overtop their rims and flood their floors.

Craters tilting toward a basin center definitely appear on the periphery of the older Nubium Basin, though much more subtly. **Pitatus** and **Deslandres** are examples of tilted craters along Mare Nubium's southern shore, and ancient **Thebit** — the large, ruined crater containing **Rupes Recta** (the "Straight Wall") — is conspicuous to the east. But once my eyes were attuned to uneven rims, I was amazed to notice that this was also true for the magnificent trio of **Arzachel**, **Alphonsus**, and **Ptolemaeus**. In each case, the western rim that is closest to the Nubium Basin is 1 to 1.5 km lower than the eastern rim. Despite having observed these craters thousands of times, I never knowingly recognized the unevenness. ✦



Gassendi's disappearing southern rim is a result of the crater forming on the inner walls of the Humorum Basin.

NICK SMITH

The Moon • February 2014

Phases

FIRST QUARTER
February 6, 19:22 UT

FULL MOON
February 14, 23:53 UT

LAST QUARTER
February 22, 17:15 UT

Distances

Apogee	February 12, 5h UT
252,420 miles	diam. 29′ 25″
Perigee	February 27, 20h UT
223,967 miles	diam. 33′ 9″

Librations

Schorr (crater)	February 4
Mare Smythii	February 5
Pythagoras (crater)	February 15
Olbers (crater)	February 20

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

S&T: DENNIS DI CICCO

Gems of the Night

Star-rich Perseus swarms with fascinating clusters and asterisms.

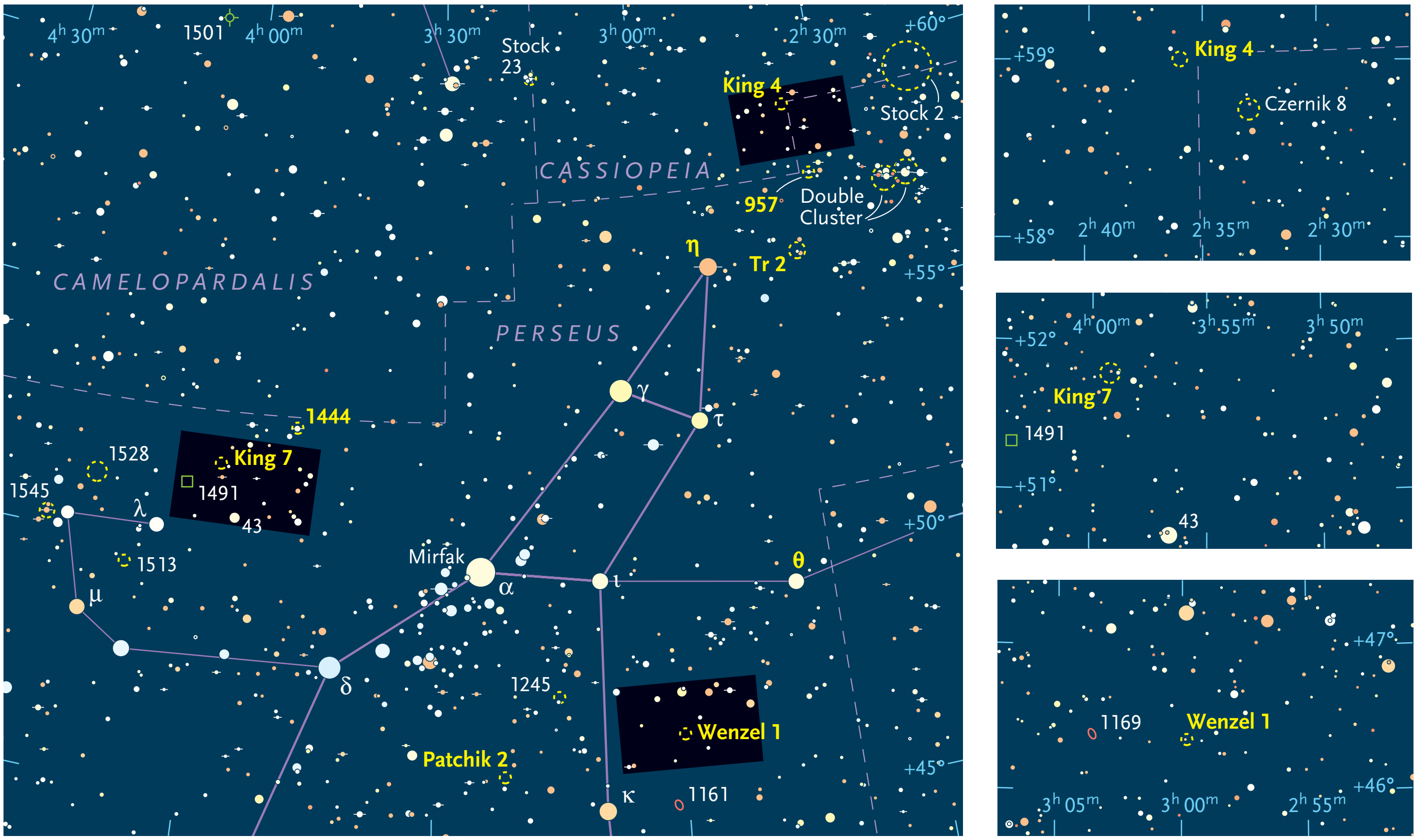
The Sky's my treasure chest,
It's there that I store
Diamonds and sapphires,
Emeralds galore
Rubies of red, jades of green
Topaz and opal, iridescent sheen
Gems of all color,
Jewels of all hue,
This treasure's all mine,
But I'll share it with you.

— George O. Pitcovich, *The Sky*

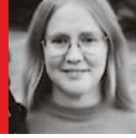
Last month we marched across Perseus, encountering many galaxies along the way. Now we'll resume our trek, leaving these remote star cities behind and visiting some smaller stellar communities within our own metropolis, the Milky Way.

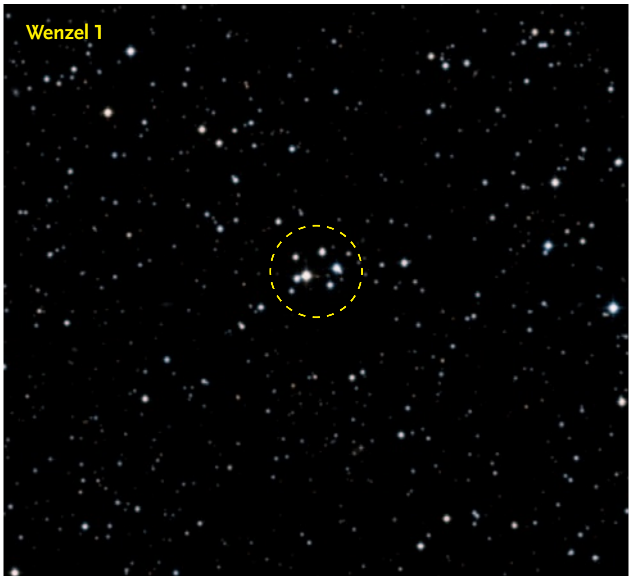
The smallest aggregations of suns are multiple stars, and we'll begin our tour with the lovely double **Theta (θ) Persei**. Through my 105-mm refractor at 47×, the bright, yellow primary star is widely separated from the much fainter spark of its companion to the northwest. The secondary star looks reddish when viewed through my 10-inch reflector at 68×. I also noticed a dimmer, bluish, third component to the west-southwest. This star is more than four times farther from the primary than the already widely separated secondary is, so it doesn't give the impression of being associated. This is borne out by studies indicating that the first two stars form a physical pair, whereas the third is not related to them.

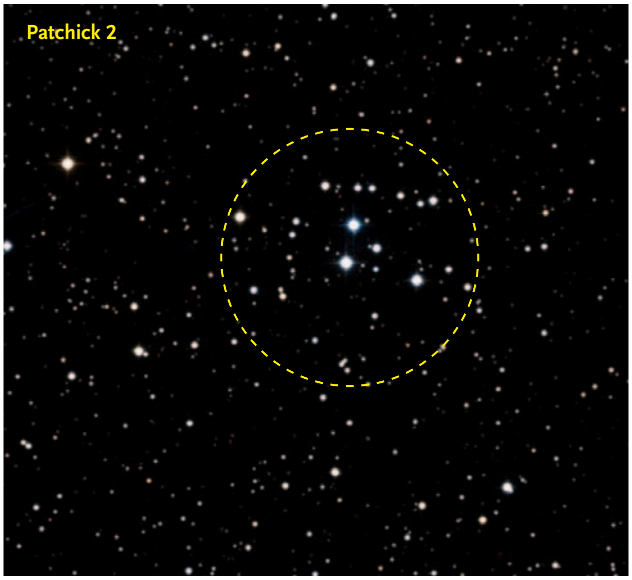
Unrelated stars can also form interesting groups, known as asterisms. German amateur Klaus Wenzel wrote to me about a compact asterism he happened upon with his 12.5-inch reflector in August 2007. It lies two-



The main chart shows stars down to magnitude 8.5. The three faintest objects also have detailed charts, which show stars down to magnitude 11.0.







POSS-II / CALTECH / PALOMAR OBSERVATORY (2)

thirds of the way from Theta to Kappa (κ) Persei. I'll take the liberty of dubbing this **Wenzel 1**.

Despite the size of the discovery telescope, Wenzel 1 is a nice group for smaller telescopes. My 130-mm refractor at 23× shows only one faint star in a tiny fuzzy spot. A magnification of 164× turns this into a squat pentagon of five stars, with a sixth star close to the brightest one — all crammed into a 1′ patch of sky. The asterism's stars are magnitude 11.0 to 13.4.

A 2.2° star-hop east-northeast from Kappa takes us to a more populous group known as **Patchick 2**. California amateur Dana Patchick discovered it from his moderately light-polluted backyard with a 13.1-inch reflector. Patchick 2 has been shown to be a group of unrelated stars, but it's more visually appealing than some true clusters.

Though my 10-inch reflector at 43×, Patchick 2 displays a knot of three 10th- and 11-magnitude stars accompanied by four very faint stars. At 166× this blossoms into a 4′ × 3′, east-west group of 16 stars with a few outliers to the east, including another 11th-magnitude star.

The first true cluster on our tour is **King 7**. An imaginary line from Mu (μ) to Lambda (λ) Persei, extended three-fourths that distance, will lead you to it. My 130-mm scope at 48× shows a faint, hazy glow that's slightly mottled and 4′ across. A 10.5-magnitude star is superimposed north of the cluster's center, a 12.5-magnitude star pins its east-southeastern edge, and a 9.8-magnitude star rests just off its western side. These are foreground stars. King 7's brightest members are magnitude 13.8. At 164× only five faint to extremely faint stars are visible, the most obvious one in the cluster's southern reaches.

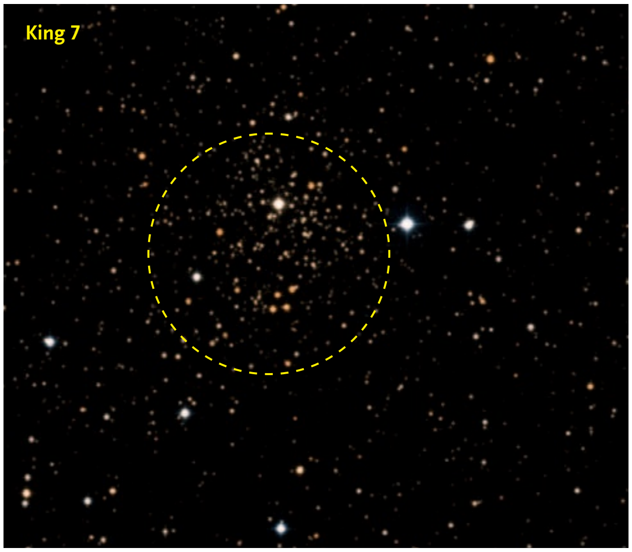
It takes a fairly large telescope to appreciate the richness of King 7. The cluster contains at least a few hundred stars, about one-third of which might be glimpsed through an 18-inch scope at a dark observing site. The excessive faintness of the stars is due to the cluster's distance of 7,200 light-years combined with a loss of four magnitudes from absorption and scattering of light by dust clouds between us and King 7. The mutual gravity of the cluster's many stars have held it together long enough to attain the ripe old age of 600 million years.

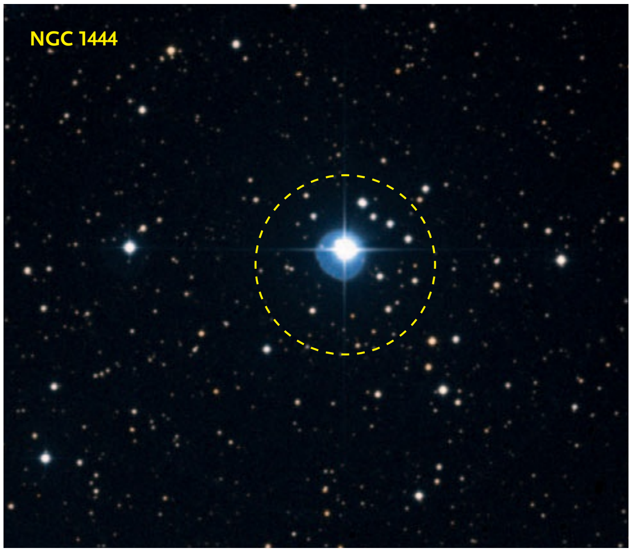
By contrast, our next cluster is star-poor **NGC 1444**. Including outliers that extend far beyond the normally listed dimensions of the cluster, only 32 stars have at least a 68% chance of being cluster members. Sparse though it may be, NGC 1444 is included in the Astronomical

Double Stars, Clusters, and Asterisms in and near Perseus

Object	Type	Mag. (v)	Size/Sep.	RA	Dec.
θ Persei	Double star	4.2, 10.8	20.3″	2^h 44.2^m	+49° 14′
Wenzel 1	Asterism	10.5	1.0′	2^h 59.8^m	+46° 21′
Patchick 2	Asterism	8.7	5.8′ × 3.3′	3^h 21.4^m	+45° 37′
King 7	Open cluster	11.6	8.0′	3^h 59.2^m	+51° 47′
NGC 1444	Open cluster	6.6	4.0′	3^h 49.5^m	+52° 39′
η Persei	Double star	3.8, 8.5	28.8″	2^h 50.7^m	+55° 54′
Trumpler 2	Open cluster	5.9	18′	2^h 36.9^m	+55° 55′
NGC 957	Open cluster	7.6	11′	2^h 33.3^m	+57° 34′
King 4	Open cluster	10.5	5.0′	2^h 36.0^m	+59° 01′

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.





POSS-II / CALTECH / PALOMAR OBSERVATORY (2)

League's Herschel 400 observing program, so some of you have probably hunted it.

Through a finderscope, you can star-hop from Lambda to 43 Persei, and from there, climb 2° north-northwest to two 7th-magnitude stars 13.6′ apart. They're the brightest stars within nearly a degree, and NGC 1444 is centered on the northern star of the duo. With my 130-mm refractor at 63×, the bright star holds a 10th-magnitude companion 8.9″ to the west-southwest, and a few extremely faint stars pop in and out of view. At 164× ten faint to very faint stars huddle around the pair in a 3½′ group.

Next we'll call on the striking double star **Eta (η) Persei**. Through my 105-mm refractor at 29×, its gems are widely separated, showing a brilliant, deep-yellow topaz accompanied by the little blue spark of a sapphire to the west-northwest. Some double star catalogs list various dimmer stars flocking around Eta as "companions," but this blue jewel is considered the most likely one to be physically bound to the bright star. On his delightful web page *Stars* (**stars.astro.illinois.edu/sow/sowlist.html**), astronomer Jim Kaler writes that if it's a true companion, it would be separated from its primary star by at least 11,500 times the distance between the Sun and Earth.

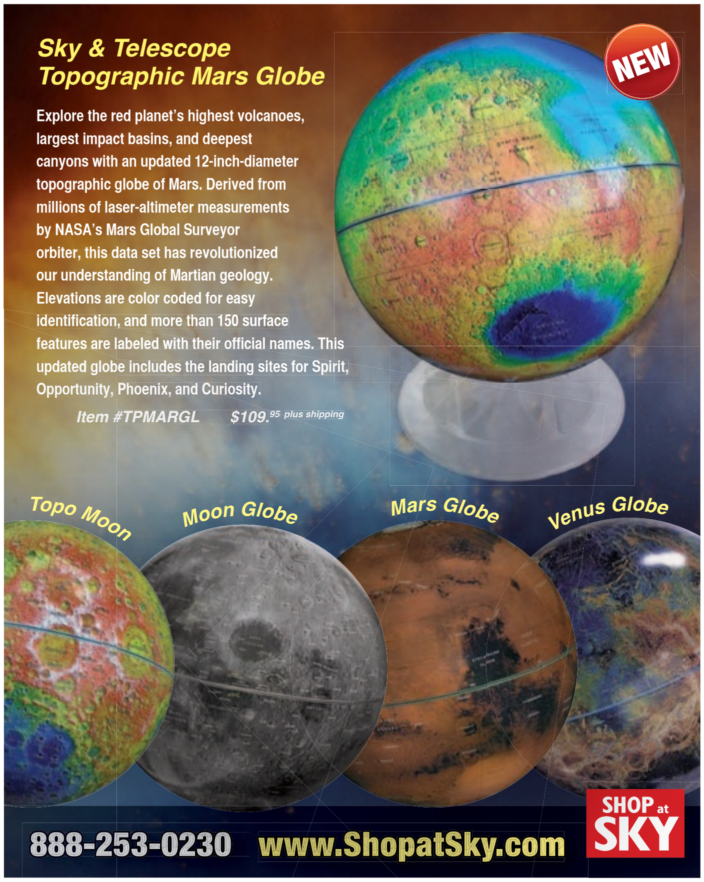
Sweeping 1.9° west from Eta brings us to the open cluster **Trumpler 2**, whose brightest star has a golden hue even through 14×70 binoculars. The star is one of eight in a jagged chain running more or less east-west for 19′. The cluster is quite interesting in my 105-mm scope at 87×, with its brightest stars forming a squashed X. Faint to very faint stars bring the total count to 25 suns. A roughly S-shaped curve of five 9th- and 10th-magnitude stars snakes southward from the group like the tail of an oddly shaped kite.

Trumpler 2 is named for Robert Julius Trumpler, who included it in his 1930 *Lick Observatory Bulletin* on open clusters. He described it as a "Pretty well defined clustering of bright and faint stars, not rich, not quite regular." It was also independently pointed out in Edward Emerson Barnard's 1927 *A Photographic Atlas of Selected Regions of the Milky Way* and in the 1931 doctoral dissertation of Per Arne Collinder (*S&T*: December 2012, page 39). Because of the latter reference, this cluster is also known as Collinder 29.

Only 1.7° north-northwest, **NGC 957** suffers a lack of attention due to the draw of its spectacular neighbor the Double Cluster (NGC 869 and 884), which deserves a visit anytime you're in the area. Still, NGC 957 is a fine cluster worthy of a look-see. To locate it, watch for a ½°- wide W of 7th- and 8th-magnitude stars that runs southeast-northwest. Through my 105-mm refractor at 87×, the W's southeastern star decorates the southern edge of the cluster. A dozen faint stars are sprinkled in a band running east-northeast to west-southwest, and the superimposed star is the easily split John Herschel double h2143. My 10-inch reflector increases the cluster's apparent population to 25 stars in 12′ × 5′.

Hovering 1.5° north-northeast of NGC 957, **King 4** is a faint, mottled haze in my 130-mm refractor at 23×. A 9th-magnitude star guards its northeastern edge. At 117× the haze is adorned by many faint to very faint specks, and some brighter stars are sprawled south of the cluster. At 164× the cluster's brightest stars form two streams. One cascades from north to south, while the other takes off from there and trends east-northeast.

Here we end our tour, but not in Perseus where we started. King 4 is just inside the border of Cassiopeia, another splendid constellation chock-full of star clusters and multiple stars. ✦


Sky & Telescope
Topographic Mars Globe
NEW
Explore the red planet's highest volcanoes, largest impact basins, and deepest canyons with an updated 12-inch-diameter topographic globe of Mars. Derived from millions of laser-altimeter measurements by NASA's Mars Global Surveyor orbiter, this data set has revolutionized our understanding of Martian geology. Elevations are color coded for easy identification, and more than 150 surface features are labeled with their official names. This updated globe includes the landing sites for Spirit, Opportunity, Phoenix, and Curiosity.
Item #TPMARGL $109.95 plus shipping
Topo Moon
Moon Globe
Mars Globe
Venus Globe
888-253-0230
www.ShopatSky.com
SHOP at SKY


A Toast to Another
Great Year!
OPT
800.483.6287
OPTtelescopes.com


At your command.
Powerful telescope control built in
Access the latest and most accurate astronomical catalogs
Optional Camera Add On provides native camera control, autoguiding, automated focus and more
Perform fast, reliable astrometric solutions (a.k.a. "plate solves")
Optional automated image acquisition and pointing calibration
Smooth panning and zooming using OpenGL graphics acceleration
Tailor the user interface to your workflow
Plan observing sessions using simple or complex database queries
Optional TPoint Add On improves telescope's pointing accuracy, aids polar alignment and more
Mac
Universal
Windows 7
TheSkyX Professional – Put Your Observatory on the Map
FIND YOUR SPACE BISQUE.COM
SOFTWARE BISQUE

 Gary Seronik

One Telescope for Everyone?

This highly portable 5-inch reflector will please beginners and fill a niche for experienced observers.

Not just another tabletop telescope, the OneSky combines a long list of interesting and useful features with a budget price. As such, the highly portable scope is sure to appeal to beginners and experienced observers alike.

USUALLY I UNBOX a telescope for a product review with mixed emotions. On the one hand, as a confirmed telescope nut and equipment junkie I'm always excited to try out a new piece of gear. But on other hand, I know that few commercial telescopes are perfect — shortcomings (sometimes disappointing ones) inevitably turn up. Rare indeed is the telescope that gets all the important stuff right. I'm happy to report, however, that the new OneSky portable Dobsonian from Astronomers Without Borders is one of those rare exceptions.

The OneSky has an unusual pedigree. Astronomers Without Borders (AWB) is an international organization based in California that operates with the motto "One People, One Sky." The telescope, on the other hand, is manufactured in China and imported by Celestron for sale in the United States exclusively by AWB. All profits from the sale go to helping fund AWB's global programs.

OneSky Reflector

U.S. price: $200 including free shipping. Scope available only in the U.S.
Astronomers Without Borders
26500 W. Agoura Rd., Suite 102-618,
Calabasas, CA 91302
astronomerswithoutborders.org

WHAT WE LIKE:

Solid mount with useful dovetail system

Nicely executed collapsing tube

Sensible choice of eyepieces and accessories

WHAT WE DON'T LIKE:

Poor collimation instructions

Incomplete baffling

ALL PHOTOGRAPHS BY GARY SERONIK

Although the 14-pound (6-kg) scope is shipped assembled (I only had to attach the red-dot finder) in a largish cardboard box, it did not survive its journey unscathed. At some point the box was dropped hard enough for the base of the focuser to leave a noticeable dent in the scope's metal tube. This damage was cosmetic, but the scope's secondary mirror was also badly out of position, certainly because of the impact. The mirror needed to be moved toward the primary mirror to be correctly aligned. This wasn't a big job, but it could have been tough for a beginner armed only with the information included in the instruction manual: the collimation directions are not only needlessly confusing, but they're also for a scope with a different style spider and focuser. This is a pity, since the OneSky comes with a nice, Cheshire-type collimation tool and a center-dotted primary mirror — features that make it easy to properly align the optics.

The 14-pound (6 kg) OneSky is a well-built, alt-azimuth reflector featuring a 5.3-inch f/5 primary mirror. It comes with a red-dot finder, two eyepieces, and a handy collimation tool.

Sizing Up the OneSky

At first blush, the OneSky is straightforward. It's a short-focus, tabletop Newtonian reflector on an alt-azimuth mount. This description applies to several popular scopes currently available, but the OneSky's details and their implementation make it a standout among the competition. For example, the scope I tested had a 5.3-inch (135-mm) f/4.8 primary mirror, instead of the usual 4½-inch (or smaller) f/4 mirrors found in other popular tabletop scopes. The OneSky's longer focal ratio provides slightly better off-axis optical performance with basic eyepieces, and the extra aperture gathers 38% more light, yielding a brighter image.

My tests revealed the quality of the optics to be very good. Star tests showed the primary mirror to be slightly undercorrected (as many mass-produced mirrors are), but free from astigmatism and edge defects. The scope comes with 25- and 10-mm eyepieces of an unstated optical design. They cover a useful range of magnifications and, by any measure, provide very satisfying views. The 25-mm eyepiece yields a magnification of 26× and shows a nearly 2° field, which makes it a breeze to aim the scope with the red-dot finder. The 10-mm eyepiece boosts the magnification to 65×, which works well for many objects, including the Moon. Even when I boosted the magnification to 130× with my own Barlow lens and the 10-mm eyepiece, the scope gave pleasingly sharp views. On a night of steady seeing, it readily split all four stars in Lyra's famous Double Double.

In all, the OneSky delivered everything I would expect from a 5-inch f/5 reflector. But optics are only part of the story — it's the mechanical features that really set this instrument apart.

The scope's optical tube attaches to the mount via a Vixen-style dovetail assembly, which locks in place with a hand knob. The dovetail lets you easily balance the scope on its altitude axis.

A nifty retracting tube is a highlight in the scope's design. When collapsed for transport or storage, the 24-inch-long (61 cm) optical tube assembly shrinks down to only 14 inches. Mentioned in the accompanying text, the dent in the tube occurred from rough handling during shipping.

Mechanical Matters

The OneSky has several nifty features rarely found in similar scopes. Most striking is the collapsing optical tube assembly (OTA). The front section — a thick plastic ring that carries the secondary mirror, focuser, and finder — is attached to a pair of metal poles that slide within a set of bushings seated in a ring mounted to the front of the main tube. When collapsed for transport and storage, the OTA measures only 14 inches long. This opens the possibility of tucking the OTA inside a piece of airline carry-on luggage. The scope's base, however, would have to travel as checked baggage. For my purposes though, I appreciated that I could easily carry the collapsed scope in and out of the house without banging its tube into the doorway.

Fully extended, the OTA is 24 inches long. Nylon screws solidly lock the sliding poles into position, although there is enough friction in the bushings to prevent the front end from retracting under its own weight.

The collapsing tube is only a plus if it's rigid, and this was indeed the case. The tube proved to be satisfyingly robust and a champ at retaining optical alignment. There was not enough collimation drift to affect the views when I moved the scope from horizontal to vertical. And even after collapsing the tube multiple times, I didn't have to tinker with the optical alignment.

The open-frame tube is well done, but the baffling could stand to be a little better. The main baffle is a 4½-inch square flap of thin plastic positioned opposite the focuser. It really should be a little bigger and extend beyond the front of the scope to prevent stray light from reaching the eyepiece: when viewing near streetlights, I found that glare could sometimes intrude into the field of view.

The two struts solidly lock in position with nylon thumbscrews. Nevertheless, even without the thumbscrews tightened there's sufficient friction in the bushings to prevent the upper tube from retracting under its own weight.

The OneSky eschews the common rack-and-pinion focuser for a helical one made of metal. This choice is a mixed blessing. On the plus side, the helical threads allow precise fine-focus adjustments, which are important for an f/5 telescope. Another plus is that the focuser isn't gummed up with the thick, sticky grease often used on low-cost scopes. It has just under an inch of travel, but this was more than enough for the eyepieces included with the scope, as well as for all the ones that I usually observe with.

On the down side, you need to be careful when focusing in the outward direction because there is no stop to prevent the drawtube from completely unthreading. The focuser also has some play in its threads. Generally, this isn't a problem, but when the scope is aimed near the zenith, the focuser can rock enough on its threads to move the eyepiece out of focus. The addition of a nylon-tipped tensioning screw on the focuser would do wonders to alleviate this problem.

The OneSky has a Vixen-style dovetail rail on the OTA, making it possible to balance the telescope by sliding it fore and aft on the mount. A nice hand knob locks the dovetail in position. This rail also lets you use the OTA on any mount that has the same dovetail system. For example, I attached the OneSky to my iOptron Cube mount for some Go To observing. And thanks to a ¼-20 threaded hole on the dovetail, you can easily attach the scope to a heavy-duty camera tripod — but the hole is not at the scope's balance point, making the assembly considerably back-end heavy when mounted this way.

The OneSky's alt-azimuth mount works very well, and I had no trouble making fine aiming adjustments even when observing at high magnifications. It's made of laminate-covered particleboard, and vibrations dampened out in only 2½ seconds. Although it's largely a matter of observer taste, I found that the mount was shipped with just the right amount of friction in azimuth bearing for easily controlled motions. Altitude friction can be fine-tuned by tightening a large hand knob — a capability that comes in handy when the scope is aimed near the zenith, where the scope becomes slightly unbalanced if heavy eyepieces are used.

The mount's single-arm support is solid, and what jiggles I noted were traced to the rubber-tipped feet on the base. I found that the scope performed better when I removed these rubber inserts. This is a tabletop mount, which means to use the scope in comfort you need a sturdy table or some kind of platform (see page 64 of this issue for tips on building one).

Although I found a few nits to pick, on balance the OneSky is a real winner and manages to get all the big-picture stuff right. It's easy to aim, comes with a sensible set of accessories, has good optics, and is highly portable. I can't imagine a beginner not being thrilled with the views it provides. It gets my vote for the best bang-for-the-buck beginner's scope currently available. Considering it sells for only $200 (including free shipping), it's too bad that it's available for purchase only in the United States.

The OneSky also has much to recommend for seasoned observers looking for a highly portable grab-and-go scope well suited for travel. All things considered, this was one telescope I was very glad to have unboxed! ✦

---

*Contributing editor **Gary Seronik** is an experienced telescope maker, user, and reviewer. He scans the skies from his home in Victoria, B.C., Canada. He can be contacted through his website: **www.garyseronik.com**.*

A key element in the telescope's baffling is a plastic shield located opposite the focuser. This worked reasonably well, but the shield was a bit too small to be completely effective in bright environments.

Unlike similar tabletop reflectors, OneSky has a nifty helical focuser rather than a rack-and-pinion model. It is excellent for fine-tuning the focus, especially at high magnifications, but there was enough play in the helical threads to let the eyepiece go out of focus when the scope was moved through a large sweep in elevation.

The OneSky consists of two main parts: the optical tube assembly and an alt-azimuth mount with a cutout forming a convenient carrying handle. Thanks to a clever dovetail system, these components can be quickly and easily separated for transport or storage.

A Tripod for Tabletop Dobs

This sturdy platform for small telescopes is easy to make.

Tabletop Dobsonian telescopes are becoming increasingly popular. Instruments such as Edmund Scientifics' venerable Astroscan, Orion Telescopes & Binoculars's StarBlast, and the new Astronomers Without Borders's OneSky instrument (reviewed on page 60 of this issue) are excellent examples of this genre. Although they are wonderfully portable, they can also be a pain in the neck to use unless placed on a sturdy table. Unfortunately, not everyone has a suitable platform at their favorite observing spot. That's where Peotone, Illinois, amateur astronomer David Fuller's Super-Simple Tripod #2 (SST2) comes in.

"I wasn't using my collection of tabletop scopes very often," Dave says. "I don't like kneeling on the ground, and the picnic table in my yard is located under 80-foot-tall trees." He tried mounting his scopes on heavy-duty camera tripods, but found them too wobbly. That's when he decided to make his own.

Dave's purpose-built tripod has the twin virtues of being easy to make and highly functional. You can put one together in an evening or two, and customize it to have your scope's eyepiece at an ideal height. The SST2 consists of only a few parts — three legs made of 2×4 lumber, a round "table" made of ¾-inch plywood, and a spreader/eyepiece rack also made of ¾-inch plywood. Add three hinges, a length of threaded rod, some nuts, bolts, and screws, and your bill of materials is complete.

Dave Fuller's Super-Simple Tripod provides a sturdy yet portable platform for his Orion StarBlast tabletop telescope.

ANGELA FULLER

The most critical step in making the tripod is cutting the top edges of the 2×4s to an angle of 22½°. This ensures that when the tripod legs are spread apart, they butt up evenly against the underside of the platform. As Dave advises, "Getting these cuts right is important — take the time to ensure the leg's top ends are flat and equal." A table saw is ideal for making these cuts, but even a handsaw will work if you bundle the three 2×4s together and make a single cut. The precise angle isn't as important as ensuring that the three legs are all the same. After that, trim the bottom ends of the legs to the length needed for the tripod height you desire. The "DIY Improvements" page of Dave's website (**http://eyesonthesky.com**) provides a handy table for determining the correct leg lengths for a given platform height.

Next, make the tabletop platform and the spreader. A jigsaw is very handy for these parts, but you can also use a coping saw. The size of your telescope's base will dictate the diameter of the tabletop. It's a good idea to make three recessed holes to accommodate the feet of your scope's base, but don't make these recesses too deep — you don't want the scope's base to end up resting on its center-pivot bolt. Next, drill holes for the threaded rod in the center of the tabletop and the center of the spreader.

Use wood screws to attach the hinges to the tops of the legs and the bottom of the table, taking care to position each leg 120° from its neighbor. Next, affix the threaded rod to the table with nuts and washers. With the legs extended outward, slide the spreader up the threaded rod and hold it in place with a washer and wing nut. Curved ends on the spreader lobes make it possible to snug up the assembly for maximum rigidity by rotating the spreader.

Dave says the tripod is far more rigid than any of the camera tripods he's tried. The legs fold up easily, and he can carry it and the telescope as a single load.

If you want to learn more about how to build your own SST2, you'll find patterns, detailed photos, and many helpful tips on Dave's website. ✦

---

*Contributing editor **Gary Seronik** is an experienced telescope maker and observer. He can be contacted through his website, **www.garyseronik.com**.*

Young Astronomer Reaches for the Stars

PIPER REID

Piper Reid tackled her first astronomy project in sixth grade, and she continued to aim high — even when life threw a seemingly insurmountable obstacle in her way.

Tom Field

Eleventh grader Piper Reid was tongue-tied when she met 2006 Nobel Prize winner John Mather. Just a year earlier, Piper had waited in line in an attempt to meet the scientist who had helped make key discoveries about the nature of the cosmic microwave background. But this time, it was Mather who came up to her and extended his hand.

Not that Piper didn't have credentials of her own. She had been tackling various astronomy projects since she was 11 years old, and her most recent had won second prize in the ExxonMobil Texas Science and Engineering Fair, fourth prize in the Intel International Science & Engineering Fair, and even garnered her the 2012 Priscilla and Bart Bok Award from the American Astronomical Society and Astronomical Society of the Pacific.

Piper is one of a number of young adults who are showing the exciting science amateurs can do from their backyards. And Piper's recent recovery from a life-threatening car accident makes her story even more impressive.

BOK AWARD Piper accepts the Priscilla and Bart Bok Award for her research. She stands with Katy Garmany, the former president of the Astronomical Society of the Pacific, and Henry Wanjune Lin, the second-place Bok recipient. The award included a trip to the 2013 annual meeting of the American Astronomical Society.

An Early Start

Piper grew up in Austin, Texas, in a home that encouraged scientific thinking. Her father, Mike, had been observing since the 1990s. So he wasn't surprised when Piper wondered out loud in sixth grade if she could make her own color-coded all-sky brightness maps, like those that appeared in these pages (*S&T*: February 2006, page 99). Mike drove his daughter all over Austin so they could take snapshots of skyglow from different locations. Piper turned the data into a science project that made it to the finals at the regional science fair.

In the following months, as she watched her father doing astronomical imaging, she found herself wanting to do more. "Don't get me wrong, his images are really great — in fact, they're beautiful," she explains. "But to me, it was a bit frustrating. He'd say, 'This is M-something. And this is M-something-else.' And I'd think to myself, I don't know why he bothers taking pictures. He should be wondering, 'How'd that get there? What's it made of?'"

Piper eventually convinced her father to trade up from his clumsy tripod to a rock-solid pier. "It wasn't too hard to talk him into the upgrade," Piper says. "I just pointed out how much better his pretty pictures would be if he had a good mount!" Of course, the pier served a dual purpose — by eighth grade, Piper had completed another science project titled "Differential Brightness Method for Detection of Extra Solar Planets."

"How cool is that?" Piper exclaims. "You can detect the transit of extrasolar planets because they dim the starlight as they move across the face of distant stars." This time, her project won first place at the Austin Energy Regional Science Festival.

Build It and It's Yours

Soon afterward, Mike brought home a box of parts for a home-built spectrometer kit. He plunked the box down and announced, "Build it and it's yours."

Piper says she was a bit intimidated by the task, but excited too. "I like to figure things by doing them. I think you learn better if you do it yourself." After some trial-and-error, she had assembled a working spectrometer.

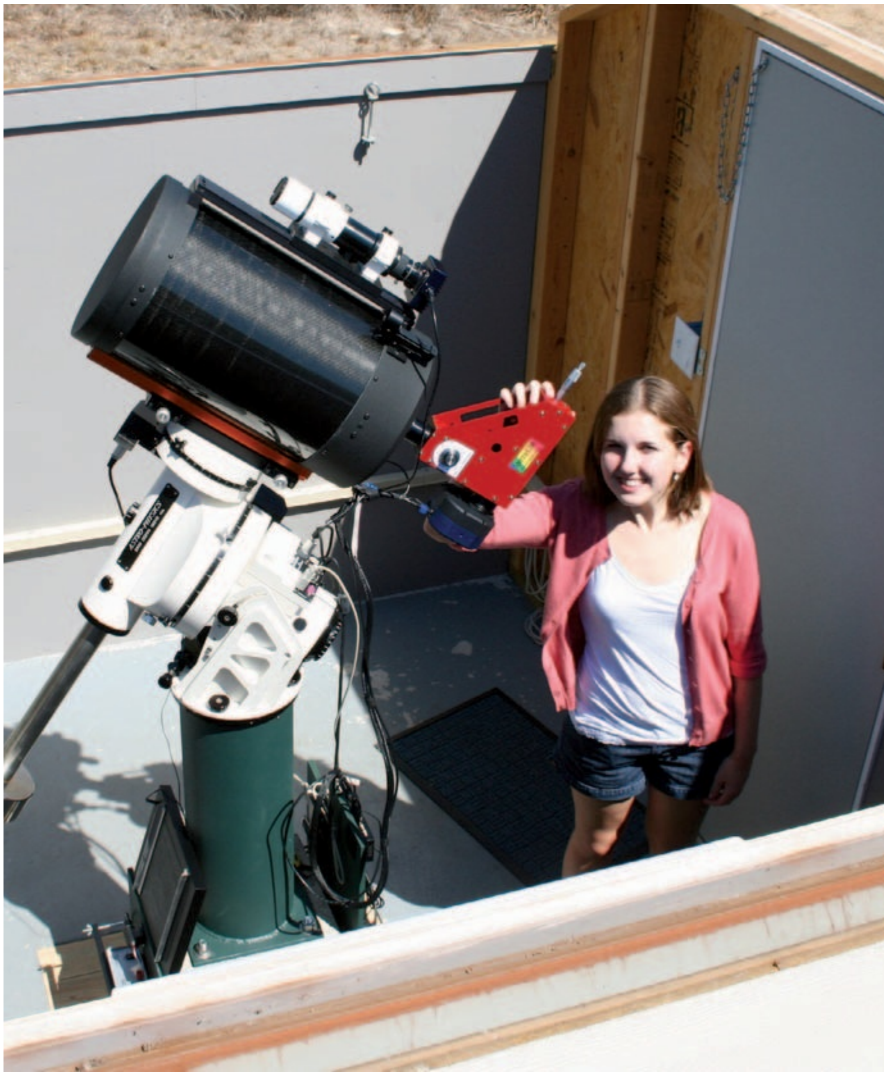
Piper used her spectrometer to analyze Jupiter's spectrum, a project that took fourth place in the regional science fair. But she knew the project, as much as she enjoyed it, wasn't pushing her boundaries. Her next project was more ambitious.

Now a tenth-grade honors student, Piper combined her new photometry and spectroscopy skills to conduct a study she titled "Photometric and Spectroscopic Analysis for the Determination of Physical Parameters of an Eclipsing Binary Star System." Her project clearly demonstrated that it's possible for a high-school student to capture the data necessary to calculate the orbital period, velocity, separation, radius, and mass of both stars in a binary system.

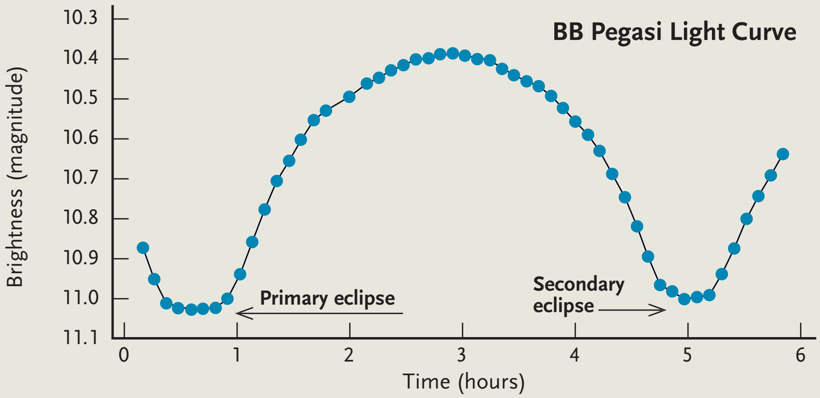
Piper started with the contact binary BB Pegasi, whose two stars orbit so closely that they touch each other. The system is relatively bright, has a short period of eclipse, and its position in the night sky makes it a good observing target. Using a Celestron C11 telescope and a QSI 583 camera, she spent five hours capturing 8-second images with *MaxIm DL* software. She stacked the images before measuring the brightness and importing the data into Microsoft Excel. The beautiful light curve that resulted showed a periodic dimming as the two stars passed in front of each other.

Piper had hoped to study the same system using spectroscopy, but it turned out to be too dim for her location and equipment. So she chose the brighter binary 57 Cygni for the spectroscopic half of her project. After capturing and stacking 12 ten-minute spectra, she calibrated and

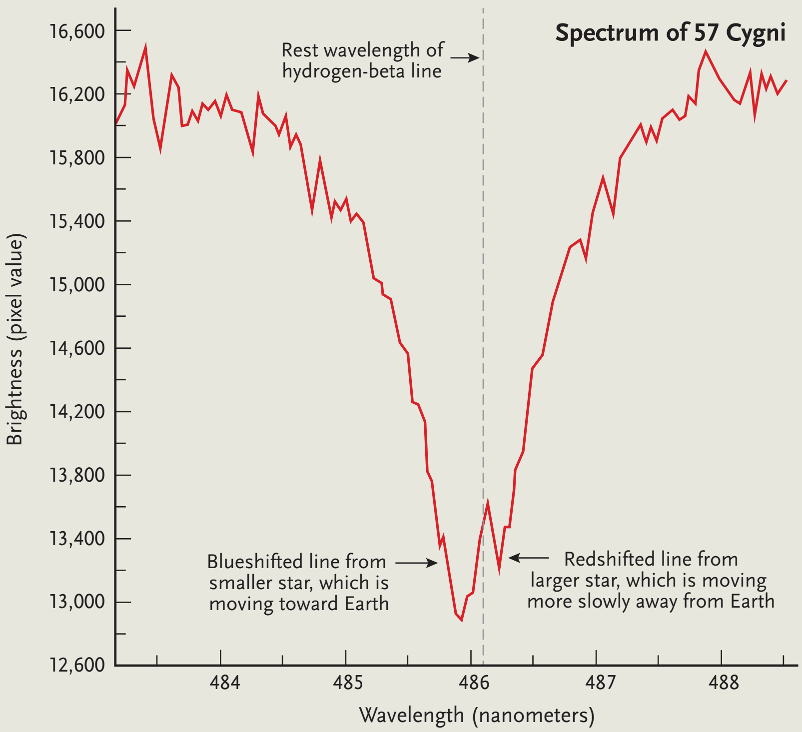
ACCOMPLISHED ASTRONOMER **Piper Reid started her first project when she was 12, measuring sky glow from various locations in Austin, Texas. Now she uses a Celestron C11 and homebuilt spectrometer to take on a range of projects.**



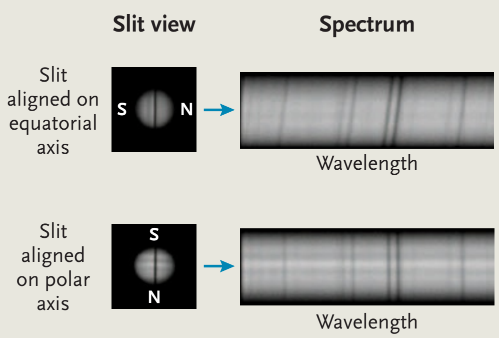
PIPER REID



BB PEGASI Piper collected 8-second shots over a six-hour period to create a series of stacked images of a contact binary-star system. The resulting light curve shows the two stars eclipsing each other. In the primary eclipse, the fainter star passes in front of the brighter one.



SPEEDING STARS Piper measured the spectrum of 57 Cygni, a detached binary system, to see how quickly its two stars orbit each other. The spectrum shows the smaller, fainter star moving toward Earth more quickly than its more massive companion moves away.



TILT AND SPIN Jupiter's spectrum along its equator (*top*) shows tilted spectral lines: half the planet rotates away from Earth (redshifting the lines), the other half rotates toward Earth (blueshifting the lines). Comparing the tilt to the straight lines measured from pole to pole (*bottom*) gives the rotation speed.

S&T: LEAH TISCIONE, SOURCE: PIPER REID (3)

viewed the spectra using *RSpec* software. As the two stars orbit a common center of gravity, their spectral lines shift to opposite ends of the spectrum. Piper used the Doppler shift to calculate the radial velocities of the two stars. "I was worried about the accuracy of my data," she says. "But when I compared my values to the accepted values, mine were only 9.5% different."

Piper's project won first place in Physics and Astronomy at the regional science fair, as well as Best of Fair, and second place in the ExxonMobil Texas Science and Engineering Fair. These awards qualified Piper to enter the Intel International Science and Engineering Fair, where she placed fourth in the Physics and Astronomy category. At the same fair, she received the prestigious Bok Award from the AAS and ASP. "I was totally shocked to win anything," she says. There were so many amazing, amazing projects there. I didn't expect to even place in the competition."

Things Fall Apart

One day before she was to begin her junior year in high school, Piper was driving home from an SAT prep course. An unidentified driver illegally passed her on a two-lane rural country road, then swerved back into Piper's lane to avoid an oncoming car. The driver clipped the front of Piper's car, running it off the road. It flipped three or four times before coming to a rest.

"It was like slow motion," she recalls. "I was looking through the windshield, watching the trees flip upside down. I couldn't believe it."

The rest of the story comes from Piper's mother, Kim: "When we arrived at the scene of our daughter's car accident, her car was upside down." Paramedics cut Piper free from the car and took her to the emergency room. But over the next few hours, her family and doctors realized she had suffered a traumatic brain injury.

"She got very strange, talking weird. She was confused, didn't know why she was there," Kim says. "When she finally came home from the hospital, our daughter had changed. For more than a month, her personality was totally flat."

Piper tried to go back to school, but she nodded off in class and took long naps in the nurse's office. When her mother picked her up after school, Piper couldn't remember what she had done all day. Finally, for the time being, the family took Piper out of school.

Piper did little but sleep for the entire first month she was home. Then, over the next several months, she worked hard to get back on her feet. Her mother gathered home-schooling materials, and they began to study together at home.

"At first, the doctors wouldn't allow me to read or watch TV or do anything," says Piper. But eventually, the doctors allowed her to read for a few minutes at a time. "I'd get headaches. My eyes would get blurry. I'd get

PIPER REID

MEETING A HERO Piper was delighted to shake hands with John Mather, a 2006 Nobel Prize winner, at the AAS meeting.

confused. I'd start solving a problem and forget what I was doing. This was really difficult for me, terrible for my self-esteem. It was scary for all of us."

But gradually, over several months, and with her family's support, Piper climbed back toward being the person that she had been before the accident. Though she still hadn't fully recovered, Piper and her family decided she would attend the AAS conference that was coming up in a few months. The Bok Award that she had received at the Intel Science Fair included an all-expense-paid trip to the conference so she could present a poster of her photometry/spectroscopy research. Attending the conference gave Piper a goal to work for. And it was a goal she succeeded in reaching.

Meeting with the Pros

I first met Piper at that very AAS conference when she came to my RSpec booth to introduce herself — I was excited to see a high-school student doing such advanced work. I visited Piper at her poster too, where I found her confidently explaining her project to a steady stream of impressed astrophysicists from all over the world.

By then, Piper was in 11th grade and had recovered from her accident. She was doing sophisticated science again and explaining her research like a pro. "I love explaining things to people," she says. "In the past, I've had to explain my projects in simple terms. But the attendees at the AAS conference totally understood what I was explaining and asked me lots of great questions. I was in heaven!"

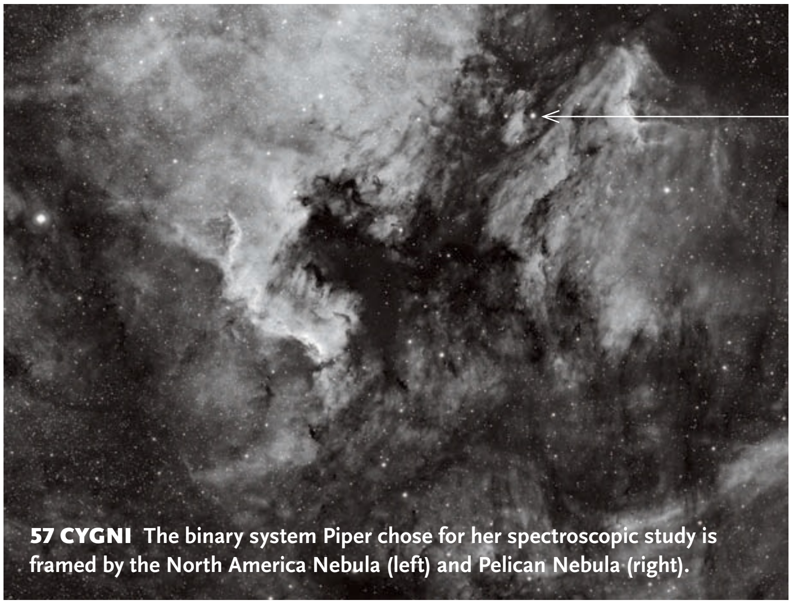
Among the hundreds of attendees to whom Piper explained her project was John Mather, Physics Nobel Laureate for his work on the microwave background. Mather wrote to me in an e-mail:

> I was very impressed by Piper's accomplishments and ingenuity. She told me about the spectrometers that she started developing at such a young age and I thought, "What a brilliant young person!" And, what a wonderful degree of progress our world has made since I was that age, when the only project a young person could imagine was to buy a few little lenses from Edmund Scientific and try to make a telescope or an elementary spectrometer. I'm really delighted to know her and see her enthusiasm for discovery.

Piper says meeting Mather was one of the high points of her year. And it gave her the confidence to pick up where she'd been before her accident. She's taking on new projects now, such as measuring the rotational speed of Jupiter and Saturn. By taking the spectrum of each planet along their equators, she measured the tilt of the spectral lines due to the Doppler shift, finding rotation rates that agree with the accepted values within 8% and 15%. That's not bad for a young amateur using backyard equipment!

Piper's accomplishments remind us that opportunities abound to take on great projects, overcome obstacles, and expand our horizons. Perhaps you'd like to do some science with your equipment, expanding your astronomical repertoire beyond visual observing and imaging? Piper shows us that we're all capable of amazing things. ✦

S&T *contributing editor* ***Tom Field*** *is the author of the popular* RSpec *spectroscopy software package and confesses to being a spectroscopy evangelist. He encourages readers to view Piper's research, as well as other exciting sample projects, at* ***www.rspec-astro.com/piper***.



57 CYGNI The binary system Piper chose for her spectroscopic study is framed by the North America Nebula (left) and Pelican Nebula (right).

S&T: DENNIS DI CICCO AND SEAN WALKER

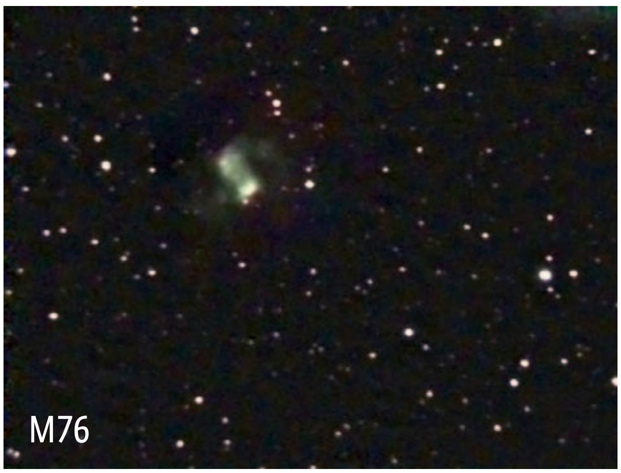
The Astrophotography HIT PARADE

Here's a target list to help budding imagers get decent results on their first night out.

Rod Mollise

What do I hear from almost all new amateur astronomers? "Rod, I want to take pictures." And by "pictures," they don't just mean snapshots of the Moon. They want vividly colored images of galaxies, star clusters, and nebulae. Although I warn bright-eyed novices that it will be a long time before they begin taking shots like those in *Sky & Telescope*'s Gallery section — if they ever do — I don't try to dissuade them. My images aren't much better, but they're mine and that makes it all worthwhile.

So what do you need to take pictures of deep-sky wonders? You need a telescope, a tracking mount, and a camera, of course, but you also need a little knowledge about your subjects. A professional wedding photographer wouldn't dream of doing a shoot without talking to the bride and groom and scoping out the wedding location, and you shouldn't go outside and start snapping blindly either. Some objects are easier to image than others, and some are more photogenic.



ROD MOLLISE

The ease of capturing a target involves several considerations. One of the most important is how difficult the subject is to focus. Even a small amount of mis-focus will bloat stars and soften detail, making a picture look worse than it should. You can use a medium-bright star of 6th to 8th magnitude to attain rough focus in short exposures. Once it is in focus, dimmer stars will help with precise focus. Some targets, such as star clusters, are easier to focus accurately than others, of course. One of my observing buddies calls globular star clusters "nature's gift to astrophotographers": the tiny, dim stars of a globular make it simple to find exact focus.

When you're getting started, you want to choose targets that are bright in your scope and camera. Short exposures of a subject that's relatively small and bright can be stacked (combined) into good results, and not having to guide the telescope eliminates a lot of potential problems when you're just starting out.

Of course, you'll want a photogenic subject. You want an object that's bright and large enough to show detail. But subjects that are too large can yield disappointing pictures. There won't be enough sky around them to provide contrast, and their light will be spread out over a large area.

I've assembled what I consider to be the most beautiful "models" for Northern observers. They're easy for beginners yet they still reward advanced imagers. I was able to

S&T: DENNIS DI CICCO

After getting all the equipment together, some amateurs starting out in astrophotography will overlook the important detail of choosing the right targets to shoot. Author Rod Mollise shares his list of the 18 best objects seen from the Northern Hemisphere, such as the gorgeous galaxy pair M81 and M82 above, that beginners can use to come away with good results on their very first night.

capture all these targets with an 8-inch Schmidt-Cassegrain telescope and an inexpensive, small-chip CCD camera using multiple stacked 30-second exposures.

Winter Targets

The Little Dumbbell Nebula, **M76** in Perseus, is a planetary nebula that is large enough and detailed enough to be attractive. At magnitude 10.0 and 2.7′ across, it's bright but not too bright. M76 is also highly detailed. Its basic two-lobed dumbbell shape shows up easily, and the better your skills get, the more details you'll capture, including dark patches within the nebula. The gas is shades of blue-green with tinges of pink-red along the edges.

There's not much to focus on here, so you'll have to focus on a nearby bright star. Can you bring out the "arms" of nebulosity that extend from the ends of the nebula and wrap around it?

M37 in Auriga is a heck of a pretty object visually with a small, wide-field telescope. I've often thought it looks more like a loose globular than an open cluster. That impression is not as strong in images, but M37 still looks darned good: a mob of small stars in a roughly spherical shape with a moderately bright combined magnitude of 6.2 and a modest 14′ diameter.

When you're processing your image, boost the color saturation and see if you can detect the red color of M37's "central" star.

Gemini's **M35** is not just another open cluster. It's

ROD MOLLISE (3)

bright (magnitude 6.2) and 14′ across. But what really makes it stand out is a "bonus object," the smaller and more distant open cluster, **NGC 2158**, 26 arcminutes south-southwest of M35. In a scope-camera setup with a large enough field, this big cluster and its companion are wonderful. The bright stars of M35 in the foreground, and NGC 2158 and its tiny stars in the background, make for a memorable image.

M79 isn't much of an object for short exposures and wide fields. Winter's only decent globular cluster is small and dim at 9.6′ in diameter and magnitude 7.7. And yet this lonely splash of stars yields a compelling picture. Photography, celestial or terrestrial, isn't always about the most beautiful model.

Spring Targets

M82 is a bright, cigar-shaped, edge-on galaxy in Ursa Major that's on everybody's favorites list for visual observing. It's great for imagers, too, though it can be difficult to get just right. Its 9th-magnitude brightness and 9.3′ × 4.4′ size suggest it's going to be fairly bright, but the figures don't begin to indicate how easy it is to overexpose. Keep exposures short so you don't burn out the dark lanes crossing the disk of this "disturbed" galaxy. And while you're in this part of the sky, the nearby magnitude 7.8 spiral galaxy **M81** is another great target, even if it's slightly large at 21.9′ × 10.5′.

The Owl Nebula, **M97**, is another legendary object I struggled with visually as a beginner. The Owl is easy for a camera, however, with the two dark patches that form its eyes popping right out of the big, round nebula. Thirty-second exposures reveal the Owl's pale pea-green color and the three dim stars cocooned in the nebulosity.

The Whirlpool Galaxy, **M51** in Canes Venatici, is the top galaxy for imagers experienced or new. At magnitude 8.7 it's relatively bright and it has the near-perfect size of 9.8′ × 7.8′. Its spiral arms and the bridge of matter extending to a passing small galaxy, NGC 5195, make for an iconic image. Use at least a 1,000-mm focal length instrument to make the Whirlpool's detail easy to see, but there's really no way to make this galaxy look bad. The spiral shape and bridge are not hard to image. More difficult, though, are the three dim "fingers" of stars extending from the northern side of NGC 5195, as well as the tiny galaxies scattered across the field.

Also in Canes Venatici, **M3** is spring's premier globular. This magnitude-6.3, 18′-diameter ball of stars is actually fairly easy to photograph. It's about the same size as its more famous sibling, M13, but its core is not quite as compact, making it easier to resolve into stars. M3 is so bright that I can focus on the cluster alone.

Summer Targets

Hercules' **M13** is "The Great Globular," but is it great for astro-imagers? Absolutely! At magnitude 5.8 and 20″ across, it's bright and easy to frame. Two bright stars in the field help with rough focusing. Ten exposures of 30 seconds each were all I needed for a passable portrait of "Herc." Any downsides? The core is compact and bright, making it difficult to properly expose. Try to bring out some core stars while still showing plenty of outer stars.

Most planetary nebulae are too small to make good subjects, but there are exceptions, and **M57**, the famous Ring Nebula in Lyra, is one. The Ring has it all. It is

Taking longer exposures can bring out the fainter extremities of your targets. The image of M27 at left uses five 30-second images, whereas the version below combines an hour of exposures to bring out the greenish ends of the nebula.

TOP: ROD MOLLISE, BOTTOM: S&T: SEAN WALKER bright (magnitude 9.4) and big (1.4′ in diameter) enough to look good at medium focal lengths of 1,000 mm and more. The Ring presents interesting detail and striking color even in brief exposures, appearing as a blue-green ring tinged with red and yellow surrounding a hazy green "donut hole."

M57 is good, but **M27**, the Dumbbell Nebula in Vulpecula, is better. It has a large enough size, 20′ across its longest dimension, and is so bright (magnitude 7.3) that short exposures will show plenty of detail within the nebula. M27's magnitude-13.9 central star shows up easily and there's plenty of color, with the Dumbbell "ends" being red, and the interior a mix of greens and whites. A challenge is to show the dimmer outer nebulosity that makes M27 look more like a football than a dumbbell, without overexposing the center.

M8, the Lagoon Nebula in Sagittarius, is sometimes called "the Orion Nebula of summer," but it's actually a better target for imagers than M42. Portions of the Orion Nebula are so bright that it's difficult to expose properly. The Lagoon is also bright at magnitude 5, but it's more evenly illuminated. At 20′ across its brightest area, M8 is a bit large for easy framing with small camera chips and longer focal lengths. Focusing is easy thanks to an open cluster of stars within the nebula, NGC 6530. There's an hourglass-shaped spot of nebulosity at the center of the western half of the nebula. Can you image it and record dimmer nebulosity at the same time?

The Ring Nebula is a bright, colorful target that offers plenty for instruments of almost any focal length. Using larger detectors such as those in most DSLR cameras may require some cropping to keep the ring from appearing lost in a sea of stars.

S&T: DENNIS DI CICCO (2)

Fall Targets

I'm not a big fan of open star clusters. What's photogenic about a loose collection of stars? Cassiopeia's **NGC 457**, the E.T. (or Owl) Cluster, is different: its bright suns, which include magnitude-5.0 Phi Cassiopeiae, form a stick figure that looks just like The Extraterrestrial. Yes, E.T. is just a bunch of stars, but it's a photogenic bunch. At 20″ across, it's easily framed using most focal lengths.

When I was getting started in CCD imaging, I was afraid to try **NGC 7331**, the Deer Lick Galaxy in Pegasus. It's relatively dim at magnitude 10 and large at 10′ across, so its light is somewhat spread out. Nevertheless, it shows up easily in a 30-second exposure. A stack of 20 of these images begins to reveal the galaxy's attractive, sweeping spiral arm.

Although the main galaxy is not very difficult to image, recording its most prominent spiral arm is. Can you also bring out the nearby small NGC galaxies, the "deer" at the deer lick?

I'd been imaging the sky for a while before I attempted the other Andromeda galaxy, **NGC 891**. It's a skinny, edge-on spiral that's 12′ long and magnitude 11.7, which is dim visually in an 8-inch telescope. Fortunately, that didn't stop my camera. Short exposures didn't just show the galaxy's disk and central bulge, they brought out NGC 891's dramatic, detailed equatorial dust lane as well.

When I was a young amateur, **M33**, the Pinwheel Galaxy in Triangulum, was one of the objects I most wanted to see. When I finally found it, it was surprisingly dim. I could make out its spiral form, but it wasn't easy. When I started taking pictures, it wasn't much better. The problem is not its brightness (it is a bright magnitude 6.4), but that it's also large, more than 1° across, which spreads out the galaxy's light. It nearly filled the field of my camera's small chip. Additional dark sky around it will make the spiral form more distinct, but it's so beautiful that it's still worth a try if your scope can frame the whole thing.

The Great Orion Nebula, M42, may be big and bright, but those two features make it a particularly vexing challenge for newbies. You might want to work on some of the other targets on this list before attempting such a surprisingly difficult object.

ROD MOLLISE (2)

The Also-Rans

Why isn't one of the sky's premier deep-sky objects, the Great Orion Nebula (**M42**), on the list? For beginning imagers it's got problems. It's too large at 40′ × 20′ to fit in the field of even a large-chip DSLR with a medium-focal-length telescope, and its core is too bright to allow novice astrophotographers to correctly expose both the outer nebulosity and the center.

And if there was one galaxy I wanted to photograph in my novice days, it was **M31**, the Andromeda Galaxy. Alas, like M42, it is too large, 2.6° × 1.1° across, for most telescopes. It's an object for a small, wide-field telescope or a piggybacked camera with a 200- to 400-mm lens at a dark site. Even then, you'll find you need processing expertise to do it justice. I'm still trying for a good Andromeda picture.

There you have it, 18 must-shoot targets for your camera. That might not sound like a lot, but once you start in on them, I guarantee you'll find they are enough to last you a lifetime of astrophotography. I can always do a better M51 or M81 or M13, and I keep coming back to them night after night. So will you. ✦

---

*Contributing editor **Rod Mollise** observes and images the night sky from his home in Mobile, Alabama.*


Special Limited Time Offer!
Solar Maximum at a minimum
LS35THα
LS35THαDX
View it live with the LS35THα for only $598 and for a limited time you can upgrade to the LS35THαDX for only $75 more!
Observe exciting solar activity. The LS35THα from LUNT Solar Systems is a complete dedicated Solar Telescope, a perfect 'grab and go' scope. The LS35THαDX comes with the larger B600 blocking filter for imaging, a Sol Searcher, 10mm eyepiece, mounting rings, dovetail and foot bracket for tripod mounting.
LUNT SOLAR SYSTEMS
2520 N COYOTE DRIVE, STE 111, TUCSON, ARIZONA 85745 • 520-344-7348 • WWW.LUNTSOLARSYSTEMS.COM
LUNT PRODUCTS ARE DESIGNED, MANUFACTURED AND TESTED IN THE USA.


FOCUS ON
BAYS MOUNTAIN PARK
Kingsport, Tennessee – email baysmtn@tricon.net
This dome shelters an 8" refractor telescope equipped with a hydrogen-alpha filter used for solar studies. The instruments are mostly used for visual observations. Video feed is available to send live images to the planetarium theater during eclipses and lunar programs. Observing nights are hosted by the staff and volunteers.
ASH MANUFACTURING COMPANY
P.O. Box 312, Plainfield, IL, USA 60544
815-436-9403 • FAX 815-436-1032
www.ashdome.com
Email: customerservice@ashdome.com
ASH DOME
Ash-Dome is recognized internationally by major astronomical groups, amateurs, universities, colleges, and secondary and primary schools for its performance, durability, and dependability. Manual or electrically operated units in sizes from 8 to 30 feet in diameter available. Brochures and specifications upon request.


✦ Design ✦ Manufacturing ✦ Installation ✦ Retrofitting ✦
Premium Everything is Standard Equipment
DFM ENGINEERING, INC
DFM Engineering, Inc.
1035 Delaware Ave., Unit D
Longmont, CO USA 80501
Phone 303-678-8143
Fax 303-772-9411
sales@dfmengineering.com
www.dfmengineering.com
photo: NASA, ESA, N. Smith (University of California, Berkeley), and the Hubble Heritage Team (STScI/AURA)
✦ Optical Servicing ✦ Upgrades / Repairs ✦ Observatory Design Consulting ✦


Join SKY & TELESCOPE in Chile
March 27 - April 4, 2014
The "astronomy capital of the world"! We'll visit world-class observatories, see breathtaking landscapes, and observe in crystal-clear night skies.
Spears Travel
TRAVEL LEADERS
800.688.8031
skypub.com/ChileTour

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

▲ **SHADOW CAST**

Cătălin Beldea

The Moon's dark shadow is visible in the sky above the clouds in this airplane photo of the total eclipse of November 3, 2013.
Details: *Nikon D7000 DSLR camera with an 18-to-200-mm VR lens at 20 mm. Total exposure was 1/60th second at ISO 800.*

▶ **THE LAGOON'S EMBRACE**

Robert Fields

This extremely deep narrowband image of M8 (bottom) and M20 reveals the faint streamers of nebulosity connecting these two popular targets in Sagittarius.
Details: *Takahashi FSQ-106ED astrograph with SBIG STL-11000M CCD camera. Total exposure was 10 hours through Astrodon narrowband filters.*

Visit SkyandTelescope.com/gallery for more of our readers' astrophotos.

▸ **CHROMOSPHERE ACTIVITY**

Jim Lafferty

Numerous dark sunspots and filaments punctuate the chromosphere, while bright prominences flicker along the solar limb in this detailed view of the Sun in hydrogen-alpha light.

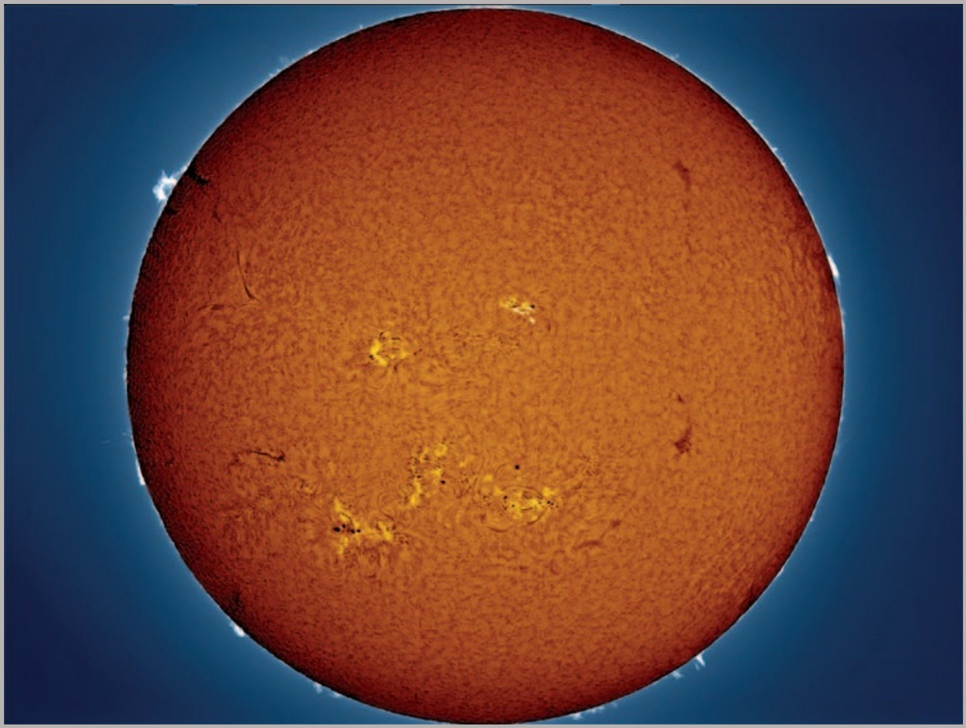
Details: *Lunt Solar Systems LS100THa solar telescope with Point Grey Research Grasshopper3 video camera. Stack of multiple exposures.*

▾ **BIG APPLE ECLIPSE**

Chris Cook

The partially eclipsed Sun rises behind the Empire State Building in New York City, as seen from New Jersey on the morning of November 3, 2013.

Details: *Canon EOS 40D DSLR with 400-mm lens at f/5.6. Total exposure was 1/4,000th second at ISO 100.*



◀ **MILKY WAY OVER CERRO TOLOLO**

Robert Stephens

The Southern extent of the Milky Way, accompanied by bright Venus at right, rises over observatory domes at the Cerro Tololo Inter-American Observatory in Chile.

Details: *Canon EOS 60D DSLR camera with 8-mm lens at f/3.5. Total exposure was 30 seconds at ISO 1600.*

▼ **SHARPLESS DUST**

Kfir Simon

Known as Sharpless 2-63, these delicate clouds of brownish interstellar dust permeate the eastern extent of Sagittarius.

Details: *Dream Telescopes 16-inch astrograph with Apogee Alta U16M CCD camera. Total exposure was 78 minutes through color filters.* ✦

SKY & TELESCOPE Market Place

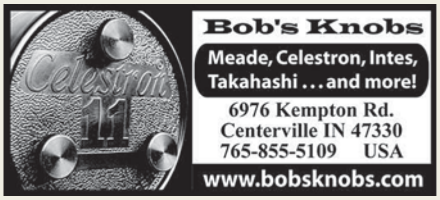
Your essential source for astronomical products

ACCESSORIES

ACCESSORIES

ACCESSORIES

ACCESSORIES



ACCESSORIES

BOOKS

COMPUTER SOFTWARE

MISCELLANEOUS

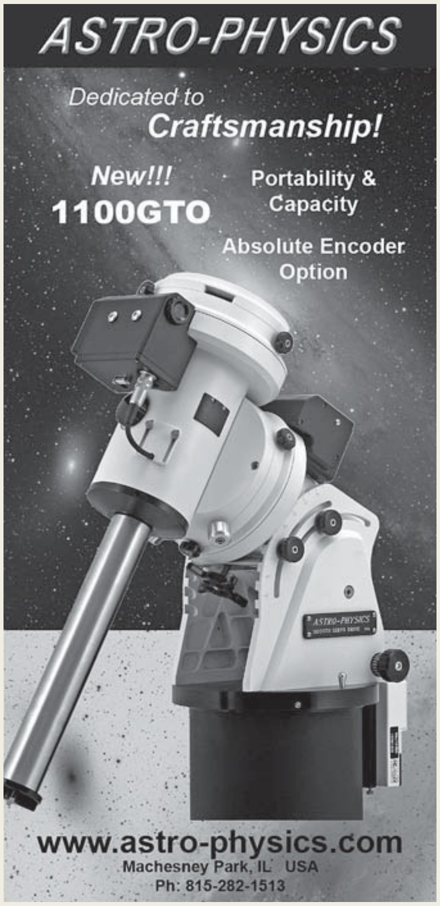
MOUNTS

ORGANIZATIONS

OBSERVATORIES / DOMES

TELESCOPES

TELESCOPES



TELESCOPES

TRAVEL

CLASSIFIEDS

ROLL-OFF-ROOF OBSERVATORY with 11" Celestron and Hyperstar, in unique southeast Arizona location. 3 Bdrm 3 Baths 2787-sq-ft home on 10 acres, built 2003, 40x40 RV/workshop & views! Pure enjoyment under the stars! $525k Sonoita Realty, Kathy O'Brien 520 405-1800.

FOR SALE: Classic A-frame, 2x10 construction, 33 mountaintop acres at 6,200' altitude, dark-sky laws in effect. Fort Davis, TX. 250K; matthewoller@yahoo.com.

FOR SALE: Beautiful 2,000 sq-ft single-story Pueblo-style home, between Las Vegas and Kingman AZ, 12' automated clamshell dome, 4BR, 3BA, 5 car garage, very dark clear skies, $195,000, for pictures and details email: easton6@roadrunner.com Phone: 702-595-8535.

REAL ESTATE: Land and homes for sale in Southern Utah's high desert – the second darkest place in North America. Noted for deep sky viewing. Properties are located between Bryce Canyon and Capitol Reef National Parks. Small remote communities surrounded by 97% government lands. Electricity, water, internet access and complete comfort while living in the wilderness! Homes on the market now ranging in price from $190,000 to $470,000. Land ranging in size from 2 to 47 acres priced from $48,000 to $350,000, all with exceptional views of the landscape and the sky. For more information, visit www.bouldermountainrealty.com or call Cathy Bagley, Broker, Torrey, Utah, 435-425-3200.

AUTHORS/SOFTWARE DEVELOPERS: is your passion astronomy and would you like to see your work published by Willmann-Bell? If so, let's explore the possibilities. Call 1-800-825-7827 or write PO Box 35025, Richmond, VA 23235.

FOR RENT: 3 BR/2BA fully furnished adobe home in ARIZONA SKY VILLAGE in Portal, AZ. Observe and photograph under the darkest, clearest and most transparent skies with astronomers from all over the world. Contact irkitzman@gmail.com 520-203-8500 www.arizona-dreaming.com.

FOR SALE: TAL 200mm Klevtsov-Cassegrain Telescope. TAL200K 8.5 Klevtsov/Cassegrain optical design telescope in excellent condition. 200mm aperture, includes these accessories: 8X50 Finderscope with mounting bracket, 90 degree star diagonal, 2X Barlow lens, 10mm Super Plossl eyepiece, 25mm Super Plossl eyepiece, crosshair reticle for eyepiece. Manufacturer's web page: www.talteleoptics.com/tal200k.html Price: $1,795 plus shipping. Write ads@SkyandTelescope.com .

Classified ads are for the sale and purchase of noncommercial merchandise, unique items, or job offers. The rate is $1.50 per word; minimum charge of $24; payment must accompany order. Closing date is 15th of third month before publication date.

Inside This Issue

Specialty astronomy equipment dealers and manufacturers are an important resource for amateur and professional astronomers alike — patronize our advertising dealers in this issue and enjoy all the benefits of their expertise.

Product Locator

AUTOGUIDERS
Santa Barbara Instrument Group (Page 3)
SBIG.com
805-571-7244

BINOCULARS
Meade (Page 88)
Meade.com
800-919-4047 | 949-451-1450

CAMERAS
Apogee (Page 15)
CCD.com
916-218-7450

FLI (Page 87)
FLIcamera.com
585-624-3760

Meade (Page 88)
Meade.com
800-919-4047 | 949-451-1450

Santa Barbara Instrument Group (Page 3)
SBIG.com
805-571-7244

EYEPIECES
Explore Scientific - Bresser (Page 53)
ExploreScientific.com
888-599-7597

Meade (Page 88)
Meade.com
800-919-4047 | 949-451-1450

Tele Vue (Page 2)
TeleVue.com
845-469-4551

FILTERS
FLI (Page 87)
FLIcamera.com
585-624-3760

Meade (Page 88)
Meade.com
800-919-4047 | 949-451-1450

Tele Vue (Page 2)
TeleVue.com
845-469-4551

FOCUSERS
FLI (Page 87)
FLIcamera.com
585-624-3760

MOUNTS
iOptron (Page 5)
iOptron.com
866-399-4587

Meade (Page 88)
Meade.com
800-919-4047 | 949-451-1450

Paramount (Page 59)
Bisque.com
303-278-4478

PlaneWave Instruments (Page 82)
PlaneWave.com
310-787-9411

Tele Vue (Page 2)
TeleVue.com
845-469-4551

OBSERVATORIES
Observa-Dome Laboratories (Page 65)
Observa-dome.com
800-647-5364

SOFTWARE
Fisch Image Lab (Page 53)
ExploreScientific.com
888-599-7597

Software Bisque (Page 59)
Bisque.com
303-278-4478

Southern Stars (Page 53)
SouthernStars.com
415-671-6254

TELESCOPES
Explore Scientific - Bresser (Page 53)
ExploreScientific.com
888-599-7597

iOptron (Page 5)
iOptron.com
866-399-4587

Meade (Page 88)
Meade.com
800-919-4047 | 949-451-1450

PlaneWave Instruments (Page 82)
PlaneWave.com
310-787-9411

Sky-Watcher USA (Page 7)
SkyWatcherUSA.com
310-803-5953

Tele Vue (Page 2)
TeleVue.com
845-469-4551

Dealer Locator

CALIFORNIA
Oceanside Photo & Telescope (Pages 59)
Optcorp.com
800-483-6287

CALIFORNIA
Woodland Hills (Page 13)
Telescopes.net
818-347-2270

OKLAHOMA
Astronomics (Page 65)
Astronomics.com
800-422-7876

To advertise on this page, please contact Lester Stockman at 617-758-0253, or Ads@SkyandTelescope.com

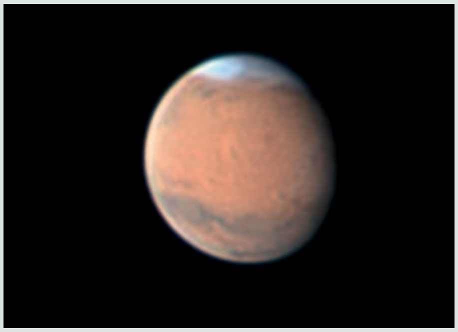
Index to Advertisers

BOTTOM: HAVEN GIGUERE / YALE UNIVERSITY; TOP: S&T: SEAN WALKER

SKY & TELESCOPE

SkyandTelescope.com
800-253-0245

IN THE NEXT ISSUE

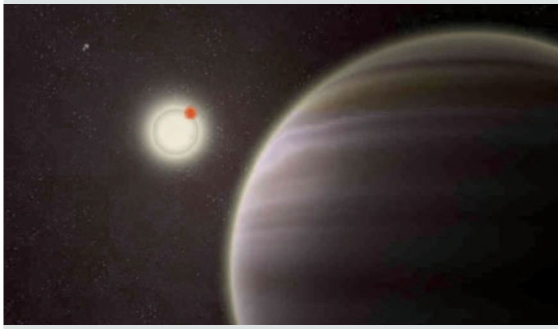


Here Comes Mars!

S&T editors explain how to get the most out of the upcoming Mars opposition.

Regulus's Disappearing Act

On the morning of March 20th, East Coasters will see one of the best stellar occultations on record.



How to Find a Planet

With Planet Hunters, you don't need a telescope or fancy equipment to discover a new world. All you need is a computer, an internet connection, and some motivation.

Observing Quasars

You can see a surprising number of quasars through modest-sized telescopes.

On newsstands January 28th!

Find us on Facebook & Twitter

Catherine Wehrey

Hubble and Copernicus

The great astronomer had a special relationship with his cat.

THE HUNTINGTON LIBRARY

Edwin Hubble gives a rare smile as he holds his cat Copernicus.

THE NAME HUBBLE invokes mental images of the Hubble Space Telescope and its photographs of colorful nebulae. But few know details of the life of its namesake ... or his cat. Astronomer Edwin Hubble (1889–1953) contributed to the study of the universe with his work at Mount Wilson Observatory in southern California. His personal and professional papers currently reside at the Huntington Library in San Marino and are studied by scholars who come here to use them for book projects, journal articles, and dissertation research.

We know much about Hubble's pursuits, his publications, and his studies. Evidence of these can be found in the underground, climate-controlled stacks of the Huntington. Among these influential archives rests proof of a deep bond with a cherished partner: his cat.

In 1946 Edwin and his wife Grace brought home a black, furry, and (initially) tiny kitten: "Its name," Edwin said immediately, "is Nicolas Copernicus." The life of this Nicolas Copernicus is well documented. He shows up in Grace's diaries and numerous photographs and is portrayed as a loyal pet, one who kept company with Edwin and Grace for many years. The part-Persian cat held a valued place in their lives.

The Hubbles catered to Nicolas's many needs. The astronomer decided that "it must have a cat-door. All cats should have [one], it is necessary for their self-respect." Pipe cleaners, the preferred amusement of choice, were a common sight at various locations in the house. At night, Nicolas was a permanent fixture at the foot of the master bed. Edwin's constant referrals to the Hubble home as "Nicolas' estate" demonstrates the exalted position of the ever-present feline.

Gifts of lizards, live birds, dead mice, and dragonflies were deposited around the house. As Grace noted, "Like all astronomers," he preferred a "midnight lunch." Ever the typical cat, Nicolas made it painfully obvious which visitors he approved of. An enthusiastic reading of *Macbeth* by a close friend sent Nicolas dashing outside, while writer Aldous Huxley was the unfortunate victim of an attempted assault by sharpened claws.

When Edwin Hubble died in 1953, Nicolas curled up beside him on the master bed, and, for months after the cremation, sat at the window of "his estate," where he had perched for many years, waiting for Hubble to return.

The photograph here shows Hubble and Nicolas posing with an armillary sphere. A look at other photographs of Hubble in the Huntington's collections reveals a man who rarely smiled for the camera. But in this photo, we see the hint of a smile and a gleam of amusement in the eyes of one of the most important figures in the history of astronomy, probably instigated by the two gleaming eyes of his black, furry shadow.

Grace Hubble recounted the relationship between man and cat in her diary:

> "When E worked in the study at his big desk, Nicolas solemnly sprawled over as many pages as he could cover. 'He is helping me,' E explained. When he sat on E's lap, he purred differently, a slow, lion-like purr.... 'Is that your cat purring?' I would ask, and E would look up from his book, smile, and nod his head."

Nicolas died on Christmas Eve, 1962. ✦

***Catherine Wehrey** is the Dibner Reader Services Assistant for the History of Science Collections at the Huntington Library.*

THE SMART SYSTEM

LX850 f/8 ACF with StarLock

Integrated, Built-in, Advanced Full-Time Auto Guiding System

LX850

Drawing on 40 years of experience and innovation, Meade Instruments introduces the latest in a long line of advanced astronomical products: the LX850. Using revolutionary new technology, every aspect of this amazing telescope system has been designed to deliver the new standard in astrophotographic and visual performance.

Shown with 12" ACF OTA

FASTER, SHARPER OPTICAL SYSTEM
The LX850 employs a fast f/8 ACF™ optical system with high-contrast baffling that assures crisp, pinpoint imaging to the very edge of the field. The all-new OTA features an internal Crayford-style, zero image-shift focusing system with a two-speed, 7:1 control that eliminates the need for a mirror lock.

PRECISION MACHINED, SOLID GERMAN EQUATORIAL MOUNT
Constructed of machined stainless steel and aircraft grade aluminum, the LX850 mount presents a rock-solid platform with precision roller bearings on both axes and a 1.75" stainless steel R.A. shaft. Its .68" diameter brass worms and 5.8" diameter, 225-tooth aluminum gears deliver smooth, precise movement with up to a 90 pound instrument load. A fully-computerized GoTo mount with GPS, the LX850 comes with a database of over 144,000 objects. All this sets atop a new super-stable tripod.

STARLOCK — FULL-TIME AUTOMATIC GUIDING
StarLock is the revolutionary new technology that makes target acquisition on your imaging sensor and accurate guiding during exposures completely automatic. StarLock uses an 80mm f/5 optic and a super wide-angle lens in a two camera system that automatically finds your target in high-precision, immediately captures a field star as dim as 11th magnitude and then guides to an accuracy of one arcsecond. There's no need for a separate guider or computer and the StarLock requires no user focusing or guide star selection. StarLock automatically programs periodic error correction and then corrects for any other errors down to virtually zero.

With the combination of the finest optics, robust mount and revolutionary new StarLock, the LX850 from Meade Instruments is the most complete astro-imaging solution available.

LX850 mount only $5,999
With 10" f/8 ACF $7,999
With 12" f/8 ACF $8,999
With 14" f/8 ACF $9,999
With 130mm APO $8,999

For more information on the LX850, or any of Meade's advanced astronomy products, just **visit meade.com** or contact an authorized dealer.

Optics Planet 800.504.5897	OPT Telescopes 800.483.6287	B & H Photo 800.482.8143
Telescopes.com 800.303.5873	Woodland Hills 888.427.8766	Adorama 800.223.2500

Canada • Khan Scopes
800.580.7160

MEADE INSTRUMENTS
Innovative products for curious minds | *since 1972*