Inside Saturn's Cassini Division p. 50

THE ESSENTIAL MAGAZINE OF ASTRONOMY

SKY & TELESCOPE

S&T Test Report: 3 Low-Cost Telescopes p. 52

Improve Your Imaging: Demystifying Flat Fields p. 72

MARCH 2011

Astronomy: The Next 10 Years

Plans for the coming decade p. 22

The Mercury Illusion p. 30

Amateurs Restore Historic Telescope p. 36

Current Binocular Highlights p. 58

$5.99 US
Display until February 28, 2011

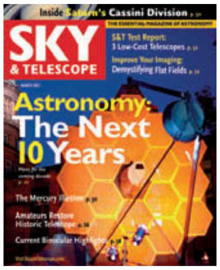
03

0 74808 02207 6

Visit SkyandTelescope.com

March 2011

VOL. 121, NO. 3



NASA / GSFC

On the cover: The James Webb Space Telescope will dominate funding for space astronomy in the coming decade.

FEATURES

THIS MONTH'S SKY

S&T TEST REPORT

JACOB GERRITSEN

CATHY COOKE EVERS

ALSO IN THIS ISSUE

Find us on Facebook and Twitter

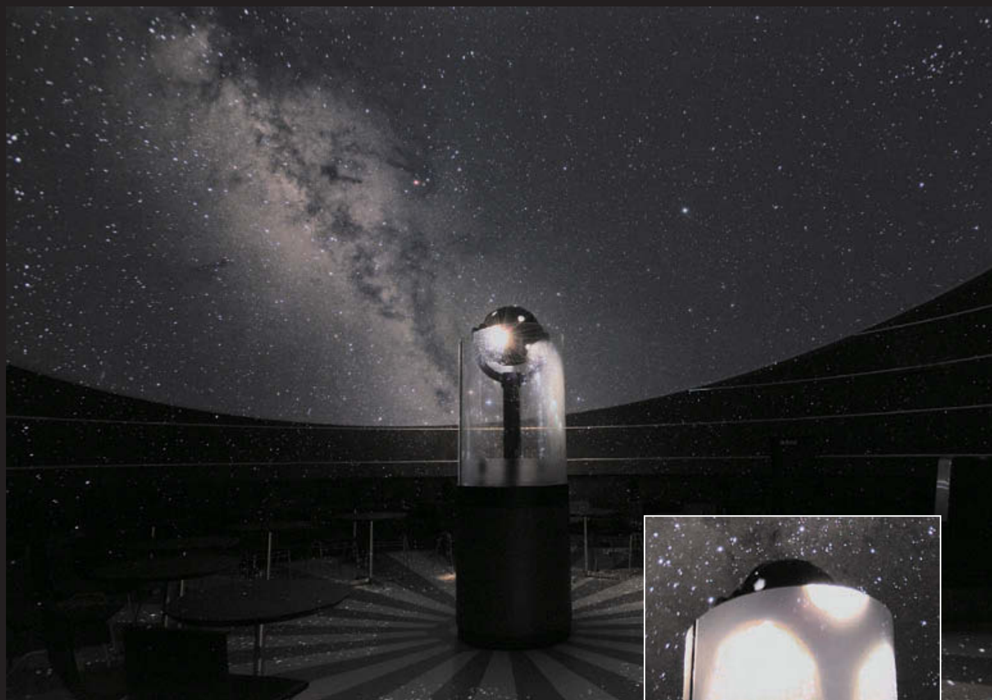
SKY & TELESCOPE (ISSN 0037-6604) is published monthly by Sky & Telescope Media, LLC, 90 Sherman St., Cambridge, MA 02140-3264, USA. Phone: 800-253-0245 (customer service/subscriptions), 888-253-0230 (product orders), 617-864-7360 (all other calls). Fax: 617-864-6117. Website: SkyandTelescope.com. © 2011 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 171, Winterset, IA 50273. Printed in the USA.

“ Night Flight ” at Haneda International Airport

GOTO INC has been publishing “My town, My planetarium” ads in Sky & Telescope since 1987. And we know that these ads have increased tourism in some of the towns as visitors come to see the planetarium. But most tourists who see the newest GOTO opto-mechanical star projector won’t be staying long. That’s because it is in the new International Terminal at Tokyo’s Haneda Airport!

At the core of this new 10 meter planetarium is the new GOTO PANDIA HYBRID system. This brand new projector for domes 6-12 meters in diameter is still being released around the world. The first installation is at Haneda. The new PANDIA is a very compact, LED-powered starball which projects a gorgeous sky and 40,000,000 star Milky Way onto the dome. It tells beautiful stories in the sky when synchronized with colorful, fulldome video. A one-of-a-kind electronic LCD shutter cylinder turns transparent or opaque at the flip of a switch, giving either realistic horizon cutoffs in the tilted dome, or a room that is filled floor to ceiling with stars. All together, the result is a true work of art.

In making this unique facility, GOTO INC was challenged to create a dome that would have multiple functions in a very busy airport. Working with the airport authority and the future operator, the dome was designed to operate as a coffee shop each morning, and as a cocktail lounge at night. Both of these uses have intimate, dimly lit tables, comfy seating, cool jazz on the audio system, and beautiful sky images overhead. In the afternoons, the dome transforms into a full-fledged planetarium with astronomy themed shows playing to excited audiences.



Unique LCD shutter cylinder in opaque mode.

The current afternoon show, “Night Flight” takes travelers from Tokyo to a destination with a different latitude and different culture, as the audience learns about changes in the sky and the constellation legends of different lands. Since Haneda is an airport, shows are short, allowing passengers to catch their next flight. But even before they step on board, they have already been to a different world!

To learn more, contact:

GOTO INC

4-16 Yazakicho, Fuchu-shi, Tokyo
183-8530 Japan
Tel: +81-42-362-5312
Fax: +81-42-361-9571
E-Mail: info2@goto.co.jp
URL: http://www.goto.co.jp

GOTO LIAISON

346 Ilimano St., Kailua, HI 96734
Toll-Free from USA: 888-847-5800
International: 808-254-1898
FAX: 808-254-1502
E-Mail: gotousa@earthlink.net
Contact: Ken Miller

Robert Naeye
Spectrum

A Quadruple Whammy for Astronomy

MY ORIGINAL IDEA for this month's Spectrum was to write about the recent decadal survey report, covered on pages 22–29, and my concerns about how the lack of funding will impact future astronomical research. But with the recent passing of four prominent astronomers, I've had a change of heart.

In August we heard the unfortunate news that Jack Horkheimer passed away. I never had the pleasure of meeting Horkheimer, but I remember watching his televised *Star Hustler* broadcasts on PBS in the 1980s, when my childhood interest in astronomy was being rekindled. Horkheimer played a key role in that process, and it wasn't just me that he inspired. He sparked an interest in the night sky among people across the country.

On October 8th we lost John Huchra of the Harvard-Smithsonian Center for Astrophysics (CfA). Huchra was not only a top-notch researcher who played a key role in mapping cosmic structure (see 50 & 25, page 10), he recently served as President of the American Astronomical Society and was a member of the decadal survey committee. (He appears in the photo on page 24.) Huchra frequently participated on the CfA softball team that plays the combined *S&T*/AAVSO staff each summer. I'll miss him as a great scientist and as a softball competitor.

On November 16th Allan Sandage died. I only met Sandage once, at his Pasadena office in the late 1990s, but I knew him as a legendary figure in observational astronomy. He made immense contributions to our modern understanding of the extragalactic distance scale, stellar evolution, galaxy formation, galaxy structure, galaxy evolution, and many other areas in astronomy.

And I was utterly shocked to hear the news a few days later that Brian Marsden died. Of these four late astronomers, I knew Marsden the best. I met him on many occasions, and just a few months earlier we were exchanging e-mails trying to arrange a lunch meeting. Marsden was a great friend of amateur astronomers, and I will always be deeply grateful to him for being so supportive of me, especially during my formative years as a science journalist.

Finally, my *S&T* colleagues and I are mourning the loss of Lynn Sternbergh Donoghue, who worked in *S&T*'s art department from 1997 to 2005. Until the very end in her battle with cancer, Lynn knew how to enjoy life, and she was one of our most creative designers. I will always have fond memories of how Lynn helped me in a big way when I moved back to *S&T* in 2003. We miss her dearly.

S&T: ROBERT NAEYE

S&T **Design Director Pat Coppola (left) poses with Lynn Sternbergh Donoghue on Rag Rock, in Woburn, Mass.**

Robert Naeye
Editor in Chief

SKY & TELESCOPE

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

The Essential Magazine of 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: custserv@SkyandTelescope.com
Phone toll free U.S. and Canada: 800-253-0245.
Outside the U.S. and Canada: 515-462-9286.
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.

ONLY MEADE INSTRUMENTS PUTS AN ASTRONOMER INSIDE YOUR TELESCOPE

LOOK & LISTEN AS ASTRONOMER INSIDE™ GUIDES YOU THROUGH THE UNIVERSE.

Originally developed for the ground breaking series of Meade LS™ LightSwitch® telescopes, Astronomer Inside is built into the new AudioStar™ controller (with speaker) included with Meade's LX90™, LT™ and LXD75™ lines of telescopes. Now the intelligence integrated into these Meade telescopes delivers all the astronomical knowledge and experience of a professional astronomer.

The incredible Astronomer Inside does all this:

- **Knows the sky so you don't have to**
  Controls the telescope to find and track any of over 30,000 celestial objects automatically
- **Takes you on a guided tour**
  Shows you the best objects in your sky from your location and time and then plays audio descriptions of those objects so you learn the details of what you are seeing
- **Has over 4 hours of audio descriptions that bring astronomy to life**
  Includes planets, stars, constellations, clusters, nebulae, galaxies and more

It's like having a personal astronomer standing next to you.

To find out more about Astronomer Inside and the entire line of Meade Instruments products, or to buy online, visit **meade.com**.

LS

6" & 8"
with LightSwitch Technology
Starting at $1,299

LX90

8", 10" & 12"
with AudioStar controller
Starting at $1,799

LT

6" & 8"
with AudioStar controller
Starting at $799

LXD75

All models
with AudioStar controller
Starting at $599

You can find the complete line of Meade products at the authorized dealers below:

Telescopes.com 800.303.5873	OPT Telescopes 800.483.6287	B & H Photo Video 800.482.8143	Scope City 800.235.3344
Woodland Hills 888.427.8766	Astronomics 800.422.7876	Canada • Khan Scopes 800.580.7160	

MEADE INSTRUMENTS
Innovative products for curious minds
since 1972

Kaci's thank-you note is accurate as well as adorable.

Young Stargazer in the Family

This past October my wife and I hosted a family reunion at our ranch. After a long day and nightfall, I set up the trusty Dob for an impromptu star party. Kaci, a precocious 6-year-old, stood out as the most enthusiastic of all the eager participants. I often wonder, however, how much my enthusiastic guests really see in the eyepiece. I've heard folks say "ooh" and "ahh" when the object of interest was not even in the field of view! So naturally I wondered what little Kaci really saw that night.

Several weeks later, the mailman delivered an oversized thank-you note from Kaci (see image at right). Her drawings at the bottom were from memory.

The first (left to right) is Albireo. The "g" and "b" are for the gold and blue colors of the double star. The next picture is M13, though I don't know the meaning of the "S." The third drawing is Jupiter, denoted by the backwards "J," and the fourth is M57 (denoted by the "N" in "Ring Nebula"). Now I have no doubt that Kaci not only "looked," she also "saw!"

I may never know what fruit is born of this newly minted childhood memory, but I feel privileged to have played a part in its making. This experience heartens me and bolsters my own enthusiasm for future star parties.

Bob Stine
Newbury Park, California

Big Bang Landmark Repaired

The letter about the condition of the Bell Labs 20-foot Horn Antenna on page 8 of the October 2010 issue of *Sky & Telescope* came to my attention ("Big Bang Landmark in Trouble," by Allan Cook). I am pleased to report that in the spring of this year, the Alcatel-Lucent Crawford Hill organization noted that maintenance was needed, and over the summer of 2010 the Horn Antenna was cleaned up and repainted.

In 2009 they paid for a set of solid-state drive amplifiers to replace the original electromechanical drive amplifiers that had quit working and seemed beyond repair. The original system is still in place to preserve the historical configuration. I believe that the present Alcatel-Lucent management (and the people who work at Crawford Hill) are proud of their considerable scientific heritage and intend to preserve the artifacts associated with it.

Robert Wilson
Holmdel, New Jersey

I grew up in Keyport, New Jersey, a town right next door to Holmdel, where the Horn Antenna was used by Robert Wilson and Arno Penzias to discover the background radiation of the Big Bang. I bought my first telescope when I was 12 and instantly got hooked on astronomy.

My family would often take trips through Holmdel just to view the trees with their fall colors and ride the hills and winding roads to view the beautiful scenery. When we would ride by Bell Labs, I would look over at the Horn Antenna, which was visible from the road, and wonder what that was and what it was used for. As I grew and became more involved in astronomy and cosmology, I realized the importance of the Horn Antenna. I moved to Florida when I was 30 and would often go back to visit relatives in New Jersey. On a visit a couple of years ago, I went to see the antenna; now knowing the importance of the instrument, I went to take my picture alongside of the horn. To my surprise, it was no longer on the hill viewable from the road! I assumed it was taken to be placed in a museum or something. That was until I read the letter from Allan Cook in your October issue. I too was upset and thought of launching a nationwide campaign to restore this historic artifact.

On the weekend of October 23rd I turned 60 and we went to New Jersey to attend my wife's 40th class reunion. My mission was to find the horn and get photos. I found the horn painted and on a gravel base with a new stone monument in place (not the one depicted in your 2007 photo). Although the antenna is back up on a hill in the maintenance area and not the original site, I was happy to see it being taken care of better than the way Mr. Cook found it. However, I believe it still needs to be in a better place with a more prominent location so the public can see and learn about it.

Steven J. Rusnak
Stuart, Florida

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. Published letters may be edited for clarity and brevity. Due to the volume of mail, not all letters can receive personal responses.

Musical Interludes

James Reid's article on Gustav Holst's *The Planets* in the January 2011 issue ("An Astronomer's Guide to Holst's *The Planets*," page 66) inspired me to think of other classical pieces with astronomical allusions and nicknames.

Both Ludwig van Beethoven in his Sonata No. 14 in C-sharp Minor and Claude Debussy in "Claire de Lune" wrote pianistic, "Moonlight" masterpieces. Mr. Reid's mention of Wolfgang Amadeus Mozart's "Jupiter" symphony (No. 41, in C Major) and Joseph Haydn's "Mercury" symphony (No. 43, in E-flat Major) also reminded me of Haydn's other works with celestial connotations. The six string quartets comprising Haydn's Opus 20 are known as the "Sun" quartets, and his comic opera *Il Mondo della Luna* ("The World on the Moon") depicts a tongue-in-cheek voyage to that heavenly body.

Henry G. Stratmann
Springfield, Missouri

To my great delight, I saw on the cover of the January 2011 issue an article on Holst's *The Planets*. Last October I asked my wife to give me the DVD of the Houston Symphony's presentation of this piece for my birthday. The NASA images along with the music make it very pleasing both to eye and ear. While I cannot say the length of each movement is the same as Holst's, it sounds beautiful. Many thanks for the illuminating feature.

Bill Murrell
Oklahoma City, Oklahoma

50 & 25 Years Ago

Leif J. Robinson

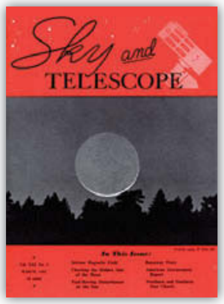
March 1961

Imaging the Lunar Far Side "On October 4, 1959, the Soviet Union launched its third cosmic rocket, which orbited an automatic planetary station (APS). The latter followed an orbit around the moon and returned toward the earth. Photographing the surface of the other side of the moon was begun, by a special command, at 3:30 Universal time on October 7th, at a distance of 65,200 kilometers from the moon's center.

"The photographing ceased 40 minutes later, when the APS was 68,400 kilometers from the lunar center. . . .

"When a photograph had been made, the miniature camera developed, fixed, and dried the specially prepared 35-mm. film that was used to allow processing at a very high temperature . . .

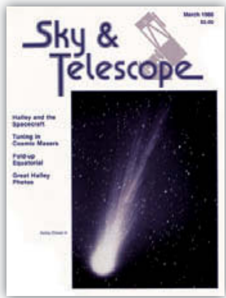
"For televising to Earth, the negative image was then converted into electrical signals. . . ."



The images from Luna 3 left much to be desired, but they allowed astronomers to prepare a reasonably accurate map of the once-invisible lunar surface on the far side. One aspect that jumps out is the scarceness of mare relative to the near side.

March 1986

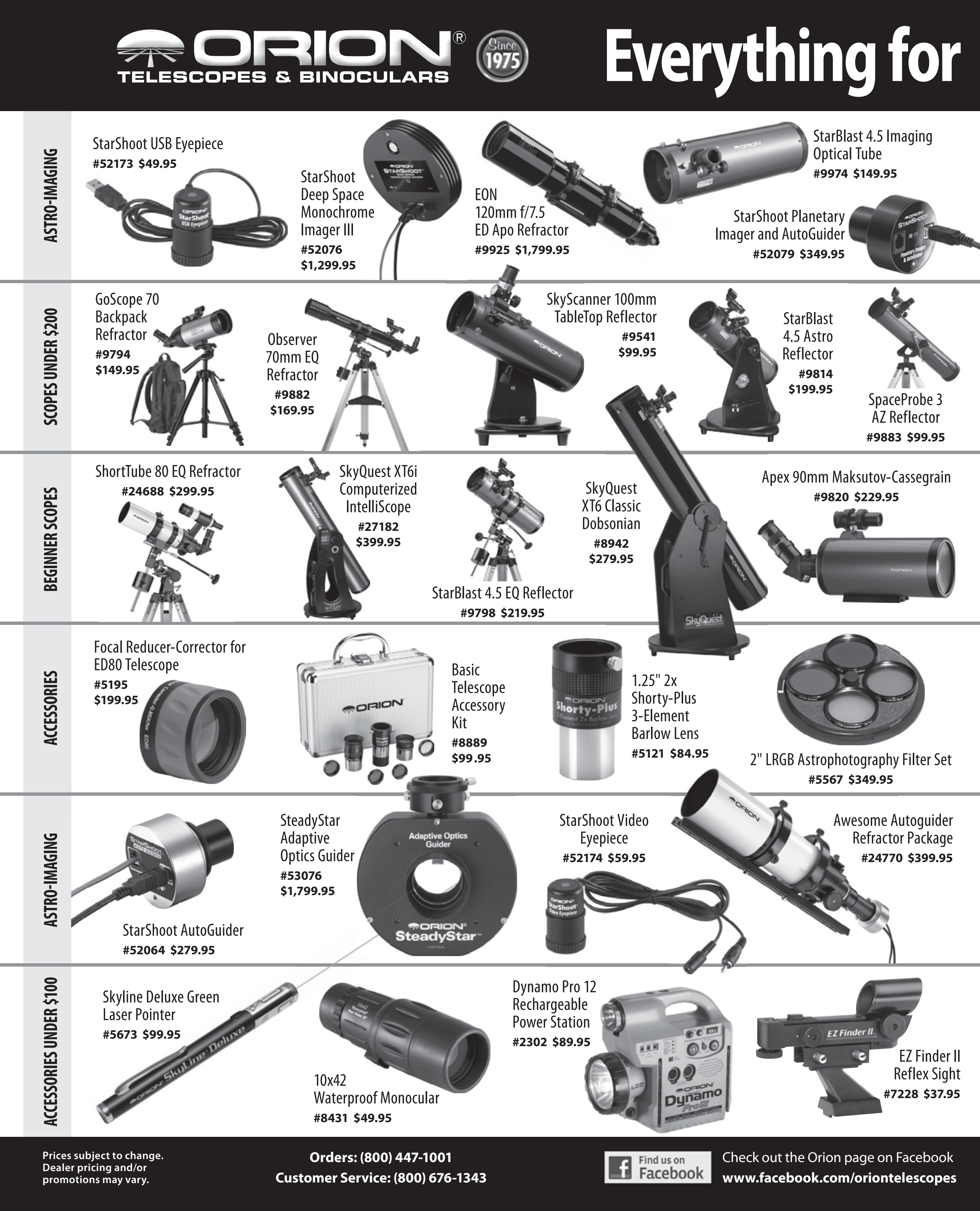
Soapsuds Universe "No one had envisioned galaxies distributed in space 'like suds in the kitchen sink.' Surprising as it may seem, galaxies and clusters of galaxies appear to be arranged on the surfaces of vast bubbles surrounding apparently empty space. . . .



"[Margaret] Geller and colleagues Valerie de Lapparent and John Huchra came to this conclusion as a result of a survey whose aim was to determine the size of the largest structures visible in the universe. . . .

"To do this they measured the redshifts of all the galaxies brighter than magnitude 15.5 in a strip of sky 117° long and 6° wide and centered near the north galactic pole. The region studied . . . contains approximately 1,100 galaxies including those in the Coma cluster."

Hints of filaments and voids had been around, both observationally and theoretically, for quite some time. The breakthrough of this particular research was the abundance of redshift data that resulted in a 3-D view. Deeper surveys involving many more galaxies have only strengthened the case since then. Sadly, John Huchra passed away on October 8, 2010 (see page 6).



ORION®
TELESCOPES & BINOCULARS
Since 1975
Everything for
ASTRO-IMAGING
StarShoot USB Eyepiece
#52173 $49.95
StarShoot Deep Space Monochrome Imager III
#52076 $1,299.95
EON 120mm f/7.5 ED Apo Refractor
#9925 $1,799.95
StarBlast 4.5 Imaging Optical Tube
#9974 $149.95
StarShoot Planetary Imager and AutoGuider
#52079 $349.95
SCOPES UNDER $200
GoScope 70 Backpack Refractor
#9794 $149.95
Observer 70mm EQ Refractor
#9882 $169.95
SkyScanner 100mm TableTop Reflector
#9541 $99.95
StarBlast 4.5 Astro Reflector
#9814 $199.95
SpaceProbe 3 AZ Reflector
#9883 $99.95
BEGINNER SCOPES
ShortTube 80 EQ Refractor
#24688 $299.95
SkyQuest XT6i Computerized IntelliScope
#27182 $399.95
StarBlast 4.5 EQ Reflector
#9798 $219.95
SkyQuest XT6 Classic Dobsonian
#8942 $279.95
Apex 90mm Maksutov-Cassegrain
#9820 $229.95
ACCESSORIES
Focal Reducer-Corrector for ED80 Telescope
#5195 $199.95
Basic Telescope Accessory Kit
#8889 $99.95
1.25" 2x Shorty-Plus 3-Element Barlow Lens
#5121 $84.95
2" LRGB Astrophotography Filter Set
#5567 $349.95
ASTRO-IMAGING
StarShoot AutoGuider
#52064 $279.95
SteadyStar Adaptive Optics Guider
#53076 $1,799.95
Adaptive Optics Guider
ORION SteadyStar
StarShoot Video Eyepiece
#52174 $59.95
Awesome Autoguider Refractor Package
#24770 $399.95
ACCESSORIES UNDER $100
Skyline Deluxe Green Laser Pointer
#5673 $99.95
10x42 Waterproof Monocular
#8431 $49.95
Dynamo Pro 12 Rechargeable Power Station
#2302 $89.95
EZ Finder II Reflex Sight
#7228 $37.95
Prices subject to change.
Dealer pricing and/or promotions may vary.
Orders: (800) 447-1001
Customer Service: (800) 676-1343
Find us on Facebook
Check out the Orion page on Facebook
www.facebook.com/oriontelescopes

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

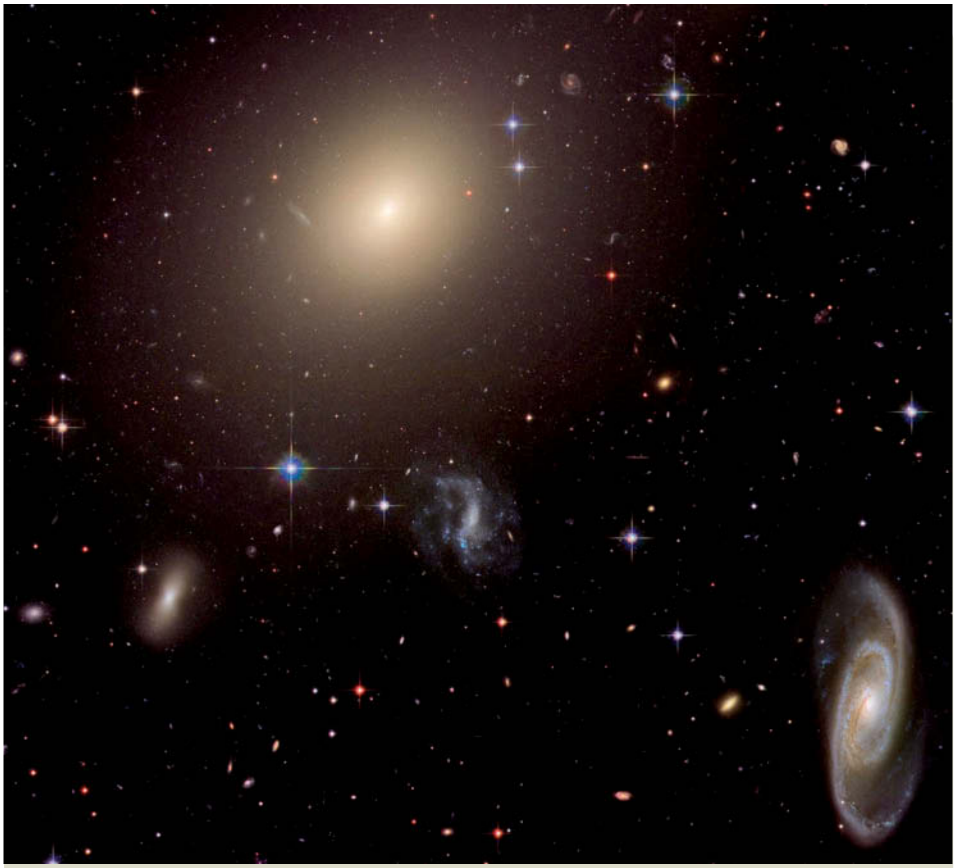
Cosmic Star Count Triples

As further proof that we don't always know the universe as well as we think, astronomers were recently surprised to discover that they've overlooked two-thirds of the stars in the universe. This huge hidden population consists of dim red dwarfs in elliptical galaxies. Because red dwarfs are so faint, they can't be seen at all in far-off galaxies, so astronomers simply assumed that they are as numerous in giant ellipticals as they are in the disk of our spiral Milky Way. Wrong.

Pieter van Dokkum (Yale) and Charlie Conroy (Harvard-Smithsonian Center for Astrophysics) took extremely high-quality spectra of eight massive elliptical galaxies in the Virgo and Coma clusters using the Keck I telescope on Mauna Kea. The spectra reveal two distinct signatures that can only come from the surfaces of red dwarfs, which have masses less than a third the Sun's. For the signatures to show at all, such stars must be some 20 times as abundant in the elliptical galaxies as in the Milky Way. That raises the total cosmic star count by a factor of three: to an estimated 3×10^{23} in the observable universe (which is defined by the travel time of light since the Big Bang).

If elliptical galaxies are this "bottom heavy," different types of galaxies clearly produce different proportions of stars. A glut of red dwarfs would also mean that giant ellipticals contain somewhat less dark matter than was previously estimated by subtracting the mass of known objects from the galaxies' gravitational masses.

"We are now observing globular clusters using the same technique," says Conroy. Globular star clusters have seemed, at least up to now, to have the same type of stellar population as elliptical galaxies.



NASA / ESA / HUBBLE HERITAGE TEAM

A giant elliptical galaxy (top) dominates the cluster Abell S0740 in Centaurus. Elliptical galaxies seem to be far richer in secretive red-dwarf stars than was long assumed.

Carbon Rules on a Hot Jupiter

The census of confirmed extrasolar planets now tops 500 — and with the Kepler mission's expected data release around the beginning of February, the number of known *likely* exoplanets will shoot well past 1,000. But aside from the sheer numbers, the cutting-edge research in exoplanets these days is in determining (if only crudely) what they're actually made of.

Take, for example, WASP-12b, discovered three years ago crossing in front of its host star 1,200 light-years away in Auriga. This giant planet is so close to its star, which is somewhat larger and hotter than the Sun, that it completes an orbit in only 26 hours. WASP-12b should have a surface temperature of at least 2,600 K (4,200°F), hot enough to glow strongly.

Because of this, astronomers can take infrared measurements just before and after the planet disappears behind the star, subtract one from the other, and isolate the glow of the planet alone. A group took measurements at four infrared wavelengths (3.6, 4.5, 5.8, and 8 microns) with the Spitzer Space Telescope, and combined them with three others (at 1.2, 1.6, and 2.1 microns) published previously. That was

ASTRONOMY MADE SIMPLE.

THE MOST SOPHISTICATED, EASIEST-TO-USE TELESCOPE ANYWHERE.
AVAILABLE IN AN 6" AND 8" APERTURES.
THE LS SERIES — ONLY FROM MEADE®.

When Meade announced LightSwitch Technology in early 2009, the amateur astronomy game changed. No more leveling. No more finding North. No more aligning. No more hassles. Just a quick flip of the switch followed by hours of enjoying the night sky. There is no more easy, simple or sophisticated telescope available anywhere today.

LightSwitch Technology

Simply flip a switch and LightSwitch automatically aligns itself in the night sky. Built-in GPS, magnetic north sensors, level sensors and a CCD camera do all the work — and within minutes you're observing!

Astronomer Inside™

Let Meade's Astronomer Inside take you on a multi-media guided tour of the night sky. Choose the Tonight's Best tour option and Astronomer Inside automatically moves the telescope to the best objects in that night's sky. At each object, listen as Astronomer Inside describes, in detail, fascinating facts and history. Attach the optional video monitor and you have a dazzling multi-media presentation that integrates rich audio and video. Or select your favorite object and your LS telescope takes you to it and tells you all about it. It's like having a personal astronomer at your side!

Meade Optics

Since 1972, Meade has consistently manufactured the finest optics available. Now you have your choice of either Meade's high-performance Schmidt-Cassegrain (SC) optics, or — for the truly discerning individual who demands the very best — Meade's Advanced Coma-Free™ (ACF) optical system delivering the sharpest, brightest image available. Both systems are made with superior materials featuring Schott® water white glass front correctors, oversized Pyrex® primary mirrors and include Meade's UHTC™ coatings for optimum light transmission. Either way, you get Meade's legendary optics.

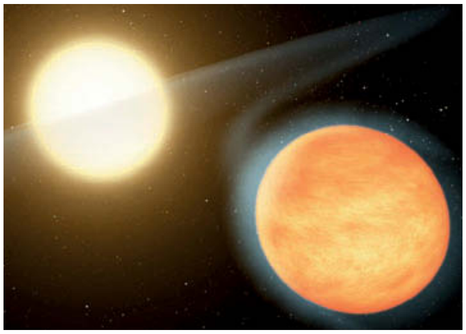
Finding out more about the LS series is almost as easy as using one — just go to meade.com.

LS-8 ACF - $1,999 • LS-8 SC - $1,799
LS-6 ACF - $1,499 • LS-6 SC - $1,299

Shown with optional LS 3.5" Color LCD Video Monitor $99

Telescopes.com 800.303.5873	OPT Telescopes 800.483.6287	B & H Photo 800.482.8143	Scope City 800.235.3344	Woodland Hills 888.427.8766	Astronomics 800.422.7876	Canada • Khan Scopes 800.580.7160

MEADE INSTRUMENTS
Innovative products for curious minds
since 1972



NASA / JPL / ROBERT HURT

WASP-12b glows red-hot in the foreground of its star (which is eight times larger) in this artist's concept. Because the planet is very close to the star, it's pulled into a slight egg shape and sheds material to form a disk even closer around the star (shown here transparent white).

enough to sample a crude but revealing spectrum of the infrared glow.

As Nikku Madhusudhan (MIT) and coauthors report in the December 8th *Nature* online, they found absorptions in the planet's atmosphere due to carbon monoxide (CO) and methane (CH_4), and, surprisingly, little sign of water vapor.

The CO, CH_4, and H_2O are surely minor constituents in an atmosphere of mostly hydrogen and helium. Still, what the authors call a "surprising lack of water and overabundance of methane" argues that WASP-12b's overall carbon-to-oxygen ratio is unexpectedly high, above 1.0. This carbon dominance is key to understanding WASP-12b's origin and evolution. In particular, its interior could be dominated by carbon-rich compounds instead of the rocky (silicate) materials we're familiar with in our solar system. A core rich in a form of carbide, graphite, or diamond is entirely possible.

Moreover, WASP-12b's dayside (which faced us when the spectra were taken) seems no hotter than its nightside, so the atmosphere must be whipped by extreme winds distributing heat around the globe.

Making Sense of Saturn's Rings

Ask a planetary scientist to list the most amazing unexplained things in the solar system, and the rings of Saturn will be right up there. We still don't know how, when, or why they came to exist.

Astronomy textbooks usually offer two possibilities: Either an early satellite strayed too close to Saturn and was pulled to shreds by tidal forces, or those same tides kept a primordial disk of matter from assembling into moons in the first place. A really good textbook might include a third option, proposed about 20 years ago, that a massive comet ventured too close to the just-forming Saturn and shed enough icy material to create a ring system.

But none of these ideas really work. Six years of close scrutiny by NASA's Cassini orbiter have confirmed what ground-based infrared observers suspected as long ago as 1990: the rings are almost entirely water ice. In fact, after allowing for the meteoritic contamination they've picked up over time, they were likely *pure* ice when they formed. Yet any disrupted satellite, or primordial building blocks, would likely have been about half ice and half rock. That's the composition of most moons and other small bodies in the outer solar system.

So how can you pulverize a moon without adding lots of rocky rubble to the rings? The answer, proposes Robin Canup (Southwest Research Institute), is to dismember it very carefully. Canup says the whole picture makes sense when you understand what happened to Saturn's moons after they formed — and realize that (unlike Jupiter) Saturn has only one remaining large satellite, Titan.

Just as the solar system's giant planets must have migrated toward the Sun in the solar system's infancy, due to interactions with the protoplanetary disk, Canup posits that most big moons that coalesced in Saturn's own primordial disk spiraled in and were swallowed by the planet. A close-in moon of roughly Titan's size would have become so hot from tidal stressing that its ice melted, causing its rocky matter to sink to the core. As it continued to migrate inward, the doomed moon crossed the threshold (known as the Roche limit) inside of which Saturn's tidal forces began pulling it apart.

The genius of Canup's model is this: the Roche limit for disrupting a rocky body is closer to a planet that the limit for an ice body, because rock is denser and thus its gravity holds it together more tightly. So, while the moon's icy exterior was falling off and spreading into a ring, the rocky core remained intact and eventually spiraled into Saturn.

This would certainly have supplied plenty of ice — perhaps 1,000 times more than the ring system holds now. But that is not a problem. Since rings tend to

No Ordinary Supernova Remnant

Most supernova remnants look chaotic and violent. But in the 400 years since its explosive birth in the Large Magellanic Cloud, the shock wave of SNR B0509–67.5 has smoothed into a delicate bubble shell. Apparently the interior material is hot enough, and the outside interstellar medium is dense and uniform enough, that most irregularities have piled up and spread evenly sideways all around the expanding shell. This view combines Hubble images of the shock front in red hydrogen light, visible-light images of the star field, and a Chandra X-ray Observatory image (blue) of the X-ray-hot gas inside. The shell is 23 light-years wide.

NASA / ESA / HUBBLE HERITAGE TEAM / J. HUGHES

Understand the Forces of the Universe

with this Fascinating, 12-lecture DVD Course by a Leading Astronomer and Professor

What forces molded the universe? Are those forces still at work, removing, changing, or adding heavenly bodies even as we gaze upward? Will humanity, and Earth itself, one day be gone? Are we alone?

In an era when science journalism is perhaps more thorough and ambitious than ever before, fascinating explorations of questions like these seem available to us almost every day—provided we have a working understanding of the scientific theories on which they're based.

In this lecture series, the astrophysicist who directs the nation's most famous planetarium makes that understanding available to anyone. **My Favorite Universe** is a spirited and intellectually engaging journey through the cosmos and its history, from before the Big Bang to the likely ways in which Earth, and perhaps the entire universe, might end.

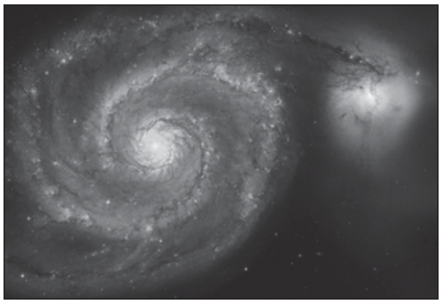
An Accessible Yet Awe-Inspiring Course

A natural teacher with a Ph.D. in astrophysics from Columbia University, Dr. Neil deGrasse Tyson has written prolifically for the public, including the series of essays in *Natural History* magazine on which this course is based. And though it was created for a lay audience and is readily accessible, the course is one in which science always takes precedence over drama.

It is certainly entertaining, often funny, even awe-inspiring at times, as befits the subject matter. But clear introductions to essential principles of physics abound throughout these lectures, including density, quantum theory, gravity, and even the General Theory of Relativity. And Dr. Tyson also includes forays into disciplines such as chemistry and biology as needed to explain events.

For example, Dr. Tyson begins one lecture at a point 13 billion years ago, when all space, matter, and energy in the known universe was contained in a volume less than one-trillionth the size of a pinpoint—about the size of an atom. By the time he finishes, the cosmos has been stretched, the planets and Earth formed, and 70 percent of Earth species wiped out by a gigantic asteroid—clearing the way for the evolution of humanity.

As Dr. Tyson notes, we are made of stardust, just as the planets are. And he has created a course



NASA, ESA, S. Beckwith (STScI), and The Hubble Heritage Team (STScI/AURA).

The Whirlpool Galaxy, as seen by the Hubble Space Telescope, is about 25 million light-years away from us.

that explains exactly how that came to be, beginning with a grounding in the basic "machinery" of matter, forces, and energy which reveals itself throughout the universe.

The Stark and Violent Beauty of the Universe

With this basic foundation in place, explanations of cosmic events fall into place, and realities of the universe are revealed in stark and often violent beauty.

We learn how Saturn's rings were formed, and why they will eventually be lost. Why low-density conditions are necessary to produce the drama of the northern and southern auroras. How black holes are formed and can wreak havoc. Why planets are round and asteroids are not.

We explore how asteroids moving through space represent threats of extraordinary consequence to Earth. Why the seemingly infinite panorama of celestial bodies revealed by the Hubble Space Telescope's famous "Deep Field" so intrigue astronomers. Why odds seem overwhelmingly in favor of some kind of life out there.

About The Great Courses

We review hundreds of top-rated professors from America's best colleges and universities each year. From this extraordinary group we choose only those rated highest by panels of our customers. Fewer than 10% of these world-class scholar-teachers are selected to make The Great Courses.

We've been doing this since 1990, producing more than 3,000 hours of material in modern and ancient history, philosophy, literature, fine arts, the sciences, and mathematics for intelligent, engaged, adult lifelong learners. If a course is ever less than completely satisfying, you may exchange it for another or we will refund your money promptly.

Lecture Titles

1. On Being Round
2. On Being Rarefied
3. On Being Dense
4. Death by Black Hole
5. Ends of the World
6. Coming Attractions
7. Onward to the Edge
8. In Defense of the Big Bang
9. The Greatest Story Ever Told
10. Forged in the Stars
11. The Search for Planets
12. The Search for Life in the Universe

About Our Sale Price Policy

Why is the sale price for this course so much lower than its standard price? Every course we make goes on sale at least once a year. Producing large quantities of only the sale courses keeps costs down and allows us to pass the savings on to you. This approach also enables us to fill your order immediately: 99% of all orders placed by 2 pm eastern time ship that same day. Order before April 1, 2011, to receive these savings.

THE GREAT COURSES®

SAVE UP TO $160!
OFFER GOOD UNTIL APRIL1, 2011

1-800-832-2412
Fax: 703-378-3819

Special offer is available online at
www.THEGREATCOURSES.com/6sky

THE GREAT COURSES®
4840 Westfields Blvd., Suite 500
Chantilly, VA 20151-2299

Priority Code 49730

Please send me **My Favorite Universe**, which consists of 12 30-minute lectures plus Course Guidebooks.

☐ **DVD $39.95** (std. price $199.95) **SAVE $160!**
plus $5 Shipping & Handling

☐ **Check or Money Order Enclosed**

* Non-U.S. Orders: Additional shipping charges apply. For more details, call us or visit the FAQ page on our website.
** Virginia residents please add 5% sales tax.
*** Indiana residents please add 7% sales tax.

Special offer is available online at www.THEGREATCOURSES.com/6sky
Offer Good Through: April 1, 2011

Charge my credit card:
☐ ☐ ☐ ☐

Account Number　　Exp. Date

Signature

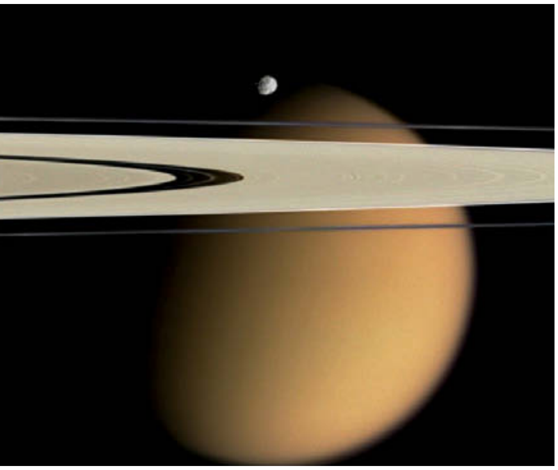
Name (please print)

Mailing Address

City/State/ZIP

Phone *(If we have questions regarding your order—required for international orders)*

☐ **FREE CATALOG.** Please send me a free copy of your current catalog (no purchase necessary).



NASA / JPL / SPACE SCIENCE INSTITUTE

In this telescopic image from the Cassini orbiter, Titan looms in the background behind Saturn's rings, and tiny, icy Epimetheus hangs in the near foreground.

spread out as their material jostles and interacts, lots of it would have spiraled into Saturn, and lots would have migrated outward — beyond the Roche limit — where it could clump together into stable ice satellites. Tethys, for example, is 660 miles (1,066 km) across, yet it has the bulk density of pure ice.

Say French ring specialists Aurélien Crida and Sébastien Charnoz, "Canup's model offers, for the first time, a convincing starting point for a consistent theory of the origin of Saturn's rings and satellites."

If she's right, the Saturnian ring system has been around for nearly 4½ billion years. Yet the ongoing gravitational tugs of war between the rings and little moons like Atlas argue that the rings formed much more recently, something like 500 million years ago. Moreover, meteorites should have dirtied up their once-pure ice in as little as 100 million years — unless the system is far more massive than has been assumed.

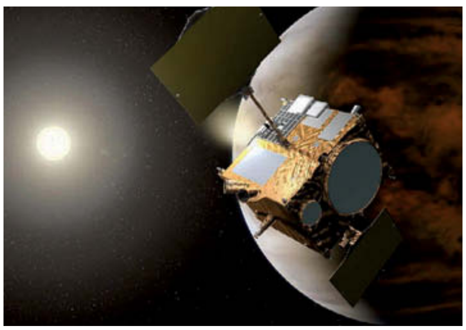
With more time and a little luck, Cassini data should allow scientists to better estimate how much meteoritic grit is soiling the rings and also determine the ring system's mass to within a few percent.

Akatsuki Fails to Orbit Venus

On December 6th Japan's half-ton Akatsuki probe, formerly known as the Venus Climate Orbiter, failed to brake into orbit as it flew past Venus. About a third of the way into its planned 9-minute rocket burn, the craft began to rotate unexpectedly and the engine automatically shut down.

Akatsuki remains alive, however. Its new solar orbit won't bring it back near Venus for about six years, and even then it's on a trajectory to miss by 2.3 million miles (3.7 million km). But project manager Masato Nakamura says that enough fuel remains on board to close that gap and attempt another orbit-insertion maneuver. However, if Akatsuki's engine nozzle is damaged as engineers suspect, this might not be possible.

Akatsuki was designed to study Venus's atmosphere from above the cloudtops down to the surface. Its science projects would have complemented those of the European Space Agency's Venus Express, which has been orbiting the planet since April 2006.



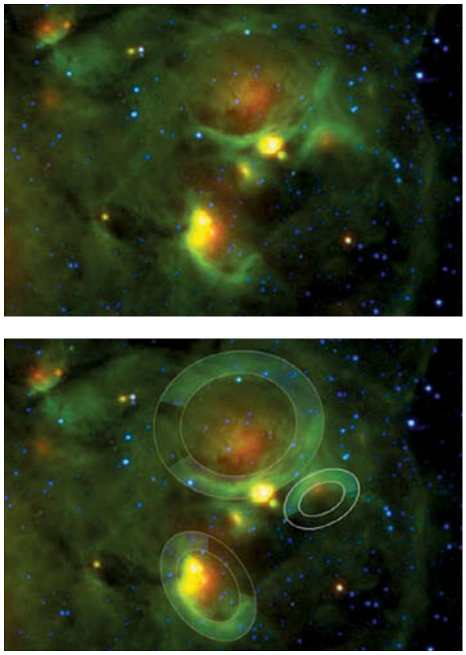
JAXA / AKIHIRO IKESHITA

Artist's concept of Akatsuki braking into orbit.

More Crowdsourced Astro Research

Humans still beat computers at some pretty routine tasks, such as classifying faint galaxies by their indistinct shapes and noticing interesting things in gigantic imaging surveys. Recognizing this, astronomers have mobilized hundreds of thousands of home volunteers to examine images that have never before been studied, or perhaps even seen, by human eyes.

NASA has recruited "clickworkers" to search its vast archive of high-resolution Mars landscapes (some with resolutions as fine as 1 meter) for important geologic features. NASA also used 26,000 home volunteers to locate microscopic specks of comet dust in the aerogel brought back by the Stardust Mission. The Stardust effort inspired the Galaxy Zoo projects, which began by setting up home users with Sloan Digital Sky Survey images to find faint supernovae and classify galaxies by Hubble type. The "Zooniverse" of volunteers is now also working on Moon Zoo, Solar Stormwatch, and others.



ZOONIVERSE (2)

Gas bubbles visible in the infrared often mark where stars are forming or dying. Some bubbles are easy to identify and trace, as shown; others are subtler. Although computers can do a fairly good job of it, human volunteers are better.

The two latest Zoo endeavors are the Milky Way Project and Planet Hunter. For the former, Robert Benjamin (University of Wisconsin) has volunteers find and characterize bubble-shaped features in images from the Spitzer Space Telescope taken for the GLIMPSE and MIPSGAL infrared sky surveys. Using graphical tools, you draw on the images to mark sizes and shapes. In addition to bubbles, you can spot and tag glowing knots of gas, little star clusters, "fuzzy red objects," and other infrared denizens of the Milky Way's stellar birthplaces. Once the project went public, the Zooniverse community (354,000 registrants and growing) soon passed 50,000 bubbles drawn. There's a lot of real estate to cover; GLIMPSE has more than 440,000 infrared images that wallpaper about 85% of the Milky Way's galactic longitude. Join up at www.zooniverse.org.

Planet Hunter serves up stellar light curves from the Kepler mission. Volunteers search for repeating patterns in the noise that might have been missed by the project's computers. Prospects here are less certain; the brain is notorious for overinterpreting randomness and seeing patterns that don't exist. "Planet Hunters is an experiment," says Yale exoplanet researcher Debra Fischer. "We're looking for the needle in the haystack." Try your hand at www.planethunters.org.

Amateur Research Widens

It's one thing to examine someone else's images; it's a whole different game to make research observations yourself. More than 100 amateur and professional astronomers, fascinated by the serious research that diligent, persistent amateurs can do with modern equipment, are expected at this year's Symposium on Telescope Science to be held in Big Bear, California, May 24–26. This will be the 30th annual gathering of a movement with a bright future.

The annual event, which overlaps the RTMC Astronomy Expo nearby, is hosted by the Society for Astronomical Sciences. At last year's gathering amateurs presented papers on obtaining high-precision light curves of asteroids and variable stars; using video cameras for asteroid occultations, Jovian satellite mutual events, and meteors; using spectroscopes to monitor the spectra of eclipsing and pulsating variable stars; and using polarimeters to examine the light-scattering properties of material in and around various celestial objects. The eclipsing star Epsilon Aurigae received special attention, with hot-from-the-spectrograph news about its ongoing two-year eclipse — including hints of rings in the dark disk that does the eclipsing.

Research projects that need more amateur attention, professionals said, include asteroid light curves and fast-cadence photometry of old novae and other cataclysmic variable stars. A workshop discussed equipment and techniques for small-telescope spectroscopy, such as monitoring *Be* stars that show changing emission lines. Attendees were treated to new-product highlights from several sponsoring companies. The progress on display bodes well for this year's meeting and the future of small-telescope science. ✦


S&T: DENNIS DI CICCO

Oliver Thizy came from France to the Symposium on Telescope Science in 2007 with the LHiRes spectrograph that his company designed and sells to amateurs.

Arsenic and Old Lakes

What does the discovery of arsenic-eating microbes really tell us about finding life elsewhere?

WHAT DID THEY EXPECT? NASA can't plant expectations of a major astrobiology story without also releasing seeds of wild speculation. The actual discovery announced on December 2nd was tame compared to alien life rumors that had mutated across the internet. Researchers working in the Mono Lake area of California had found microbes that, unlike any other known organism, seem to use arsenic instead of phosphorus in DNA and other crucial molecules. This is important because astrobiologists often list the biogenic elements — carbon, hydrogen, oxygen, nitrogen, sulfur and phosphorus — as essential for life anywhere.

An epidemic of criticism soon erupted. Did the researchers actually demonstrate that arsenic is replacing phosphorus in DNA? Did these microbes really evolve to do this in the wild, or were they merely made to go along with "the plan" in an unnatural laboratory situation?

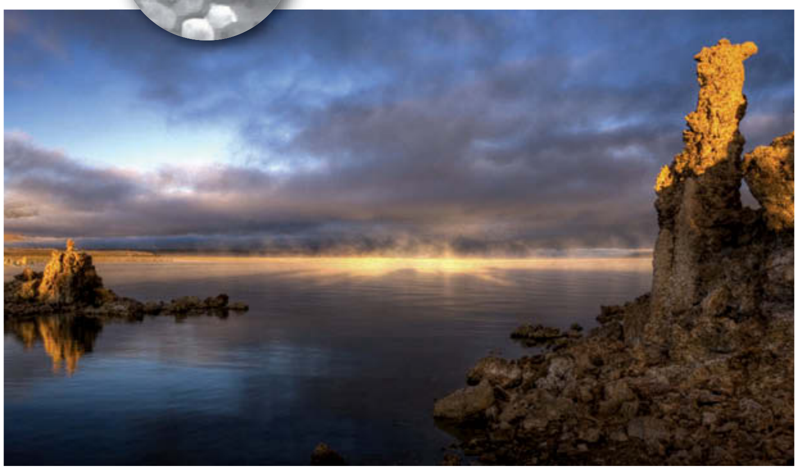
The press conference encouraged sensational news stories about "arsenic-based life," a "fundamentally new form of life," and even a "second genesis" or a "shadow biosphere" on Earth. But if these critters can actually use arsenic where the rest of us need phosphorus, does this really have huge implications for the search for alien life?

Yes and no. It's certainly an expansion of life's known limits and chemical bag of tricks. But these microbes are still carbon based. They don't represent "arsenic-based life," and they don't reveal a shadow biosphere or a distinct origin. No, these are clearly our relatives and, like the rest of us, they use giant carbon molecules to build cells and carry information. They reveal the edges of Earth's biosphere to be a bit wider than we imagined. This shows we will have to look farther afield for any true shadow biosphere, for life that exists in conditions so different from ours that carbon or DNA cannot rule.

The discovery may actually help astrobiologists resist an intellectual trap. At the press conference there was discussion of how to alter future missions to Mars or elsewhere to search for arsenic. But that's the wrong lesson. We don't need to start looking specifically for arsenic on other planets. Rather, the take-home message should be that we cannot assume we know what the biogenic elements are. Any of them. We still have no idea if life elsewhere will even be based on organic (carbon) chemistry. It's too easy to assume that all life must be just like life here. I don't believe we're capable of thinking clearly about the prospects for life that is built on fundamentally different chemical or physical systems. We're always looking for ourselves out there. We can't think of anything better, but that may say more about us than life in the universe.

We can follow our geocentric hunches about alien biochemistry, as long as we remain alert for life's general signature in anomalous chemistry and disequilibrium. What we do know is that life takes advantage of excess energy and redistributes it in ways that affect the local equilibrium. Whatever it eats or breathes, it will produce waste and exhaust that will change its environment. While we search for what we think life is, we should keep in mind that all we really know is what life does. ✦

5 microns

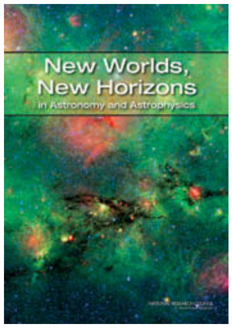


MONO LAKE In this California lake researchers found microbes *(inset)* that can use arsenic rather than phosphorous.

NASA, INSET: JODI SWITZER BLUM

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

Astronomy's Crystal Ball



THE REPORT Two years of effort from dozens of people went into this 270-page book.

THE NATIONAL ACADEMIES PRESS

A recent report will set the research agenda for the coming decade.

For the past half century, the American astronomical community has enjoyed remarkable success getting built the extraordinary ground-based and space telescopes it needed. Some of these telescopes have cost billions of dollars. Some have involved hundreds of scientists working together. All have required cutting-edge technology that could have easily failed.

On top of these practical difficulties, astronomers have also had to convince members of Congress, largely uneducated and uninterested in astronomical affairs, to fund these risky and expensive ventures. Despite these obstacles, the telescopes were built, and they have revolutionized our understanding of the universe.

How have astronomers done it? Their effort has always begun at a Washington think tank. Every 10 years or so, the National Academy of Sciences commissions a committee of astronomers to put together a decadal survey, describing the research anticipated in the next decade and the kinds of new telescopes this research will require. The U.S. government has repeatedly made an effort to follow these recommendations, building a high percentage of what the astronomers have asked for.

Robert Zimmerman

After almost two years of effort, the sixth decadal survey was published in August 2010, calling for, among other things, the construction of large ground-based telescopes and a powerful infrared telescope in space.

Whether this most recent decadal survey will be as successful as the past six, however, remains to be seen. "The astrophysics budget isn't going up," notes Edward Weiler, NASA's associate administrator for science. "We don't live in a world where NASA prints money." Worse, the continuing large cost overruns to build the James Webb Space Telescope (JWST) are having an impact that could extend not only into this decade but into the decade beyond.

Past Decadal Surveys

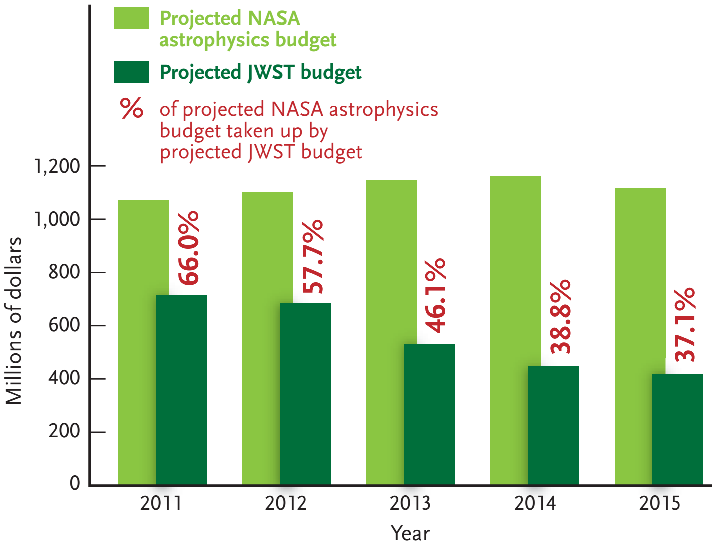
Though the first "decadal" report was written in 1964, the history of the decadal surveys truly began in 1972. The 1964 report focused solely on ground-based astronomy, and as the 1960s space race was then in full bloom and the potential for space-based astronomy was rapidly becoming evident, astronomers immediately realized that a new survey was necessary, and it should include both ground- and space-based proposals.

The subsequent 1972 report, written by a committee chaired by Jesse Greenstein (Caltech) and dubbed *Astronomy and Astrophysics for the 1970s,* was the result of four years of discussions among almost all the important astronomers in the country. Its significance for late-20th-century astronomy cannot be overstated. Not only did its recommendations lead to the construction of important observatories such as the Very Large Array

The entire decadal survey report, and a summary, can be found at www.nap.edu/catalog.php?record_id=12951.

TOO BIG TO FAIL? This full-scale model shows the enormous size of NASA's James Webb Space Telescope, which will launch no sooner than 2015. If JWST is launched and functions as planned, it will almost certainly make great discoveries in the fields of galaxy formation, star formation, and exoplanets.

NASA



JWST BUDGET PRESSURES

This diagram compares the projected NASA astrophysics budget and the projected JWST budget for the next 5 years. The budget projections come from different sources, and both could face significant future revisions. Still, the projections clearly demonstrate the fundamental problem facing astronomers: With JWST consuming such a large percentage of NASA's astrophysics budget, there is little money available to develop other space observatories. But JWST's costs should also be put in perspective. NASA is expecting to receive about $20 billion in 2011, meaning JWST will take up only 3.5% of the agency's budget in that year, and a smaller percentage in future years. In addition, NASA's budget is only about 0.5% of the overall U.S. federal budget.

S&T: LEAH TISCIONE; SOURCE FOR NASA ASTROPHYSICS BUDGET: WWW.NASA.GOV/PDF/420990MAIN_FY_201_%20BUDGET_OVERVIEW_1_FEB_2010.PDF; SOURCE FOR JWST BUDGET: HTTP://WWW.NASA.GOV/PDF/499224MAIN_JWST-ICRP_REPORT-FINAL.PDF

(VLA) in New Mexico, the 3-meter NASA Infrared Telescope Facility on Mauna Kea, the Einstein X-ray Observatory, and two other high-energy space observatories, its success solidified the pattern of decadal surveys for the next four decades.

The subsequent three decadal surveys, in 1982, 1991, and 2001, each had their own specific impact on astronomy. For example, the 1982 report recommended the construction of an advanced orbiting X-ray telescope, an orbiting far-ultraviolet spectrograph, and an expansion of the VLA to link it with other radio telescopes around the globe. All three were built: the Chandra X-ray Observatory, the Far Ultraviolet Spectroscopic Explorer (FUSE), and the Very Long Baseline Array (VLBA).

DONALD SHAPERO

DECADAL SURVEY COMMITTEE Standing (left to right): Paul Vanden Bout, Joshua Frieman, Juri Toomre, Michael Turner, Debra Elmegreen, Adam Burrows (almost hidden in the back center), Fiona Harrison, Claire Max, Tim Heckman, John Carlstrom, Martha Haynes, Dan McCammon, Tom Young, Marcia Rieke, Scott Tremaine (mostly hidden in the back right), and Steve Ritz. Kneeling: Michael Moloney, Rob Kennicutt, the late John Huchra, chairman Roger Blandford, Jonathan Lunine, and Steve Battel. Not Pictured: Lars Bildsten, Lynne Hillenbrand, and Neil Tyson. Burrows and Moloney attended meetings but were not official committee members.

Similarly, the top recommendation of the 1991 decadal survey, the Space Infrared Telescope Facility (SIRTF), became NASA's Spitzer Space Telescope, launched in 2003. The 1991 survey also pushed for the completion of the SOFIA flying observatory (which is just now beginning full operation, see the October 2010 issue, page 22) and an international partnership to construct 8-meter telescopes in both the Northern and Southern hemispheres. These telescopes, Gemini North and Gemini South, are currently making major contributions.

These astronomical decadal surveys have been so successful that other scientific fields are now emulating them in order to better influence Congress's funding decisions. For example, the Earth science community produced its own decadal survey in 2007, recommending that NASA and the National Oceanic and Atmospheric Administration (NOAA) maintain at all costs their capability to study Earth's atmosphere and how various factors influence it. This panel recommended a whole program for Earth observation for the next decade, including 14 NASA missions and 3 NOAA missions, many of which have since been accepted.

Writing the 2010 Survey

The latest astronomy decadal survey committee was chaired by Roger Blandford, the Director of the Kavli Institute for Particle Astrophysics and Cosmology at Stanford University. The committee of 23 scientists from 20 different institutions first surveyed the astronomical community to get a sense of what astronomers thought the focus of the next decade should be. Not only did committee members spend two years attending meetings across the country, they took the advice of nine additional subpanels appointed by the National Research Council. Astronomers also submitted to the committee nearly 450 white papers, outlining in great detail all manner of research goals along with a plethora of ground- and space-based telescope proposals.

This information helped Blandford's group structure and write its report. "At the beginning, the thing seemed an impossible task," recalls committee member Jonathan Lunine (currently on sabbatical at the University of Rome, Tor Vergata). "But in fact, having the panels, having their conclusions, having the white papers which gave a really good cross section of what the community was thinking about, made the process much easier."

The committee spent many meetings going over this information, sometimes revisiting prior decisions when members had second thoughts. "There was a lot of debate," recalls Lunine. "You come to the next meeting after having decided some things at the previous meeting and you find you have to go over it again."

"We were very happy with our results, but it wasn't easy to get there," adds committee member Lynne Hillenbrand (Caltech).

In the end, the committee agreed that astronomy research in the next decade will center around three topics: studying the formation of the first galaxies, finding the closest habitable exoplanets, and solving the mysteries of dark energy, dark matter, and a variety of other questions in fundamental physics.

The committee then turned to the various government agencies (NASA, the National Science Foundation, and the Department of Energy) that fund the telescopes necessary to do this research and asked them for rough budget estimates. They also asked an outside group to provide independent cost estimates for developing various projects, which would help the group avoid recommending telescopes that might experience large future cost overruns. Unfortunately, the expected budgets for astronomy over the next decade generally appeared flat, with little anticipated growth. Stating the obvious, the committee concluded, "This report is written at a time when the nation's finances are severely stressed."

The resulting report, titled *New Worlds, New Horizons in Astronomy and Astrophysics* and released on August 13, 2010, therefore included a somewhat limited number of recommendations — listed in priority order — for both space and ground-based projects.

In space, the survey's number one recommendation calls for a near-infrared 1.5-meter space telescope dubbed the Wide Field Infrared Survey Telescope (WFIRST), estimated to cost around $1.6 billion. The concept of this space telescope was actually a merging of three similar near-infrared proposals submitted to the committee by astronomers: the Joint Dark Energy Mission/Omega, the Microlensing Planet Finder, and the Near-Infrared Sky

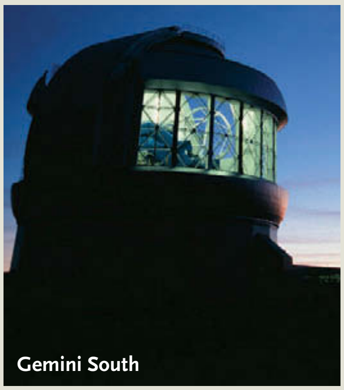
PAST WINNERS

These observatories were all assigned high priority by previous decadal surveys. With the possible exception of SOFIA (which is just beginning science operations), all of these projects have been *extremely* successful.

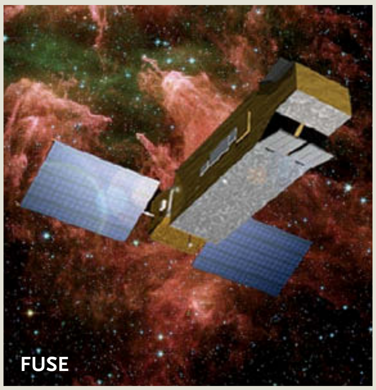

VLA
S&T: ROBERT NAEYE

SOFIA
NASA / TOM TSCHIDA

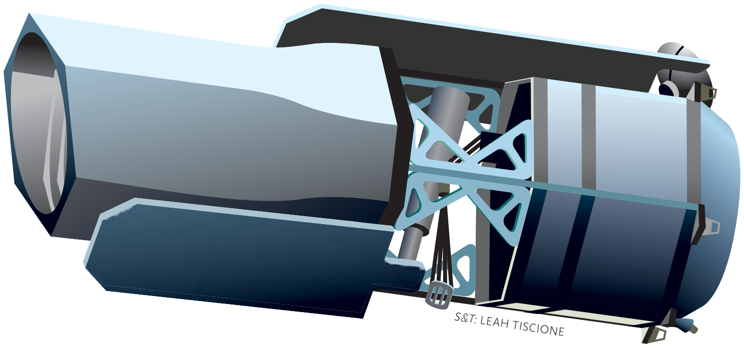

Spitzer
NASA


Gemini South
GEMINI OBSERVATORY


IRTF
NASA IRTF


FUSE
NASA

Chandra
NASA



WFIRST WAS FIRST The committee gave its highest space-based observatory ranking to the Wide Field Infrared Survey Telescope. No single astronomer or team of astronomers specifically proposed the WFIRST mission, but it combines the science goals of several different proposals. The spacecraft is in the very early stages of its design, so this illustration is based largely on guesswork.

Surveyor. Though all three had different science goals, their hardware was very similar, making a merger into one project relatively easy. "What we did was broaden the science goals," explains Hillenbrand. "If you're going to launch this mission it shouldn't do just microlensing or just sky survey or just dark energy. We wanted it to do all three of these things."

For ground-based research, the committee assigned top priority to the Large Synoptic Survey Telescope (LSST). This 8.4-meter optical telescope, now under development for an estimated cost of about $465 million, is scheduled for completion in 2016 (*S&T:* September 2008, page 30). Unlike other large ground-based telescopes, LSST will have a very wide field of view, 9.6 square degrees, allowing it to repeatedly image the entire available sky every three nights. This data stream will enable astronomers to track changes in the night sky that have never been tracked before, from every kind of variable star to the discovery of new comets and asteroids. "LSST was viewed as pathfinding science, feasible, and ready to go," says Hillenbrand.

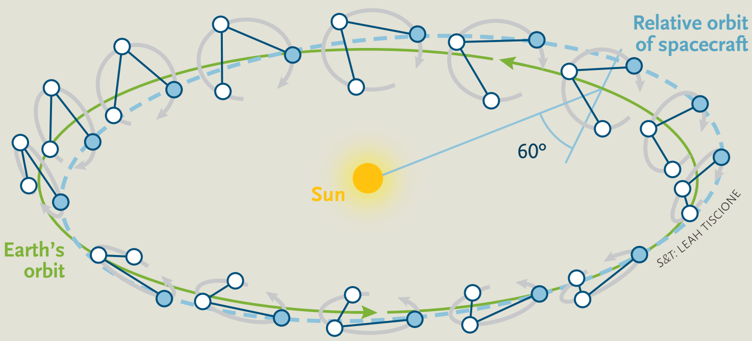
The report also called for the federal government to become a partner in one of the giant ground-based optical telescopes now in the planning stages, either the 24.5-meter Giant Magellan Telescope or the Thirty Meter Telescope (*S&T:* April 2008, page 20).

The report recommended increased NASA participation in the Laser Interferometer Space Antenna (LISA), a space mission designed to detect gravitational waves, as well as commit monies to begin the design work for a large international high-resolution X-ray space telescope. But scientists on these missions hardly consider themselves "winners." By not listing either mission as top priority for a large space mission, the committee has probably postponed their launch by at least a decade.

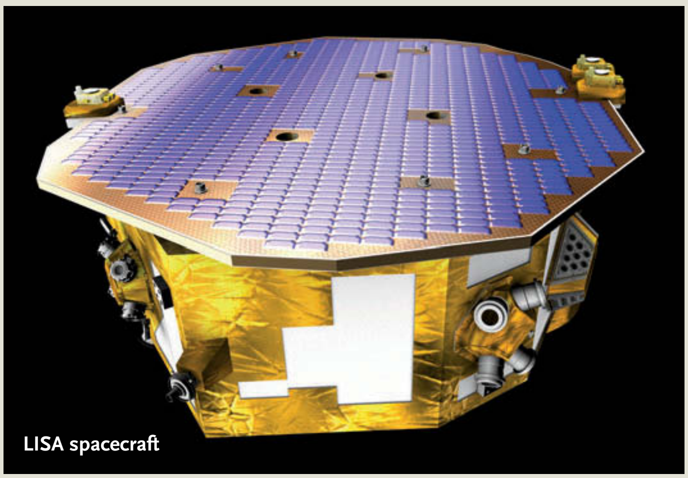
The committee also studied expensive missions whose launches lie years in the future. Missions like these, such as Terrestrial Planet Finder and the Space Interferometry Mission, were recommended for modest levels of funding for continuing technology development. "We thought it prudent to have more technology development first, since discoveries or changing circumstances could lead in a different direction for a given problem," says committee member Debra Elmegreen (Vassar College).

The report included many other recommendations covering a wide range of activities (see page 29). For example, it asks NASA to increase its support for the construction and launch of moderately sized space telescopes, similar in scale to existing low- and medium-cost (but highly productive) observatories such as Swift and GALEX.

THE "LOSERS"



LISA's Orbit



ESA

The Community's Reaction

Since its release, the response of the astronomy community has been generally supportive, though somewhat muted. Many astronomers are disappointed in the report's lack of visionary proposals, especially in the field of exoplanet research. "In the sense that they mentioned exoplanets, I think they could have painted a grander view of what is possible," notes Matt Mountain, Director of the Space Telescope Science Institute.

"They write many, many words about exoplanets, but the program is unclear," says Shrinivas Kulkarni (Caltech). "There's not much money to do much. It's not a bold vision." Rather than the WFIRST effort to use gravitational microlensing to gather statistics of exoplanets toward the galaxy's bulge, Kulkarni would have preferred an effort to actually observe and characterize the features of nearby exoplanets. "Let's go look for them around nearby stars, because that is the next frontier," says Kulkarni.

The committee's recommendations also didn't provide much support for astronomers doing cutting-edge spectroscopy, especially at ultraviolet wavelengths, which can only be done from space. As noted by Mountain, "If you look at some fields — ultraviolet spectroscopy and the interstellar medium — that community didn't get the kind of follow-on missions it was hoping for."

Similarly, though many astronomers had hoped that the survey would recommend the construction of a new optical/ultraviolet space telescope to replace the aging Hubble Space Telescope, the committee declined to do so. As committee member and cosmologist Michael Turner (University of Chicago) noted, "The technology is not quite there yet to build a 4- or 8-meter optical/ultraviolet telescope at an affordable cost."

Instead, the decadal survey recommended that NASA spend $40 million over 10 years on the technology research required to make such an optical/ultraviolet space telescope project possible in the next decade. "The hope is that with the investment that will be made over the decade, we will be ready to go in 2020," Turner says.

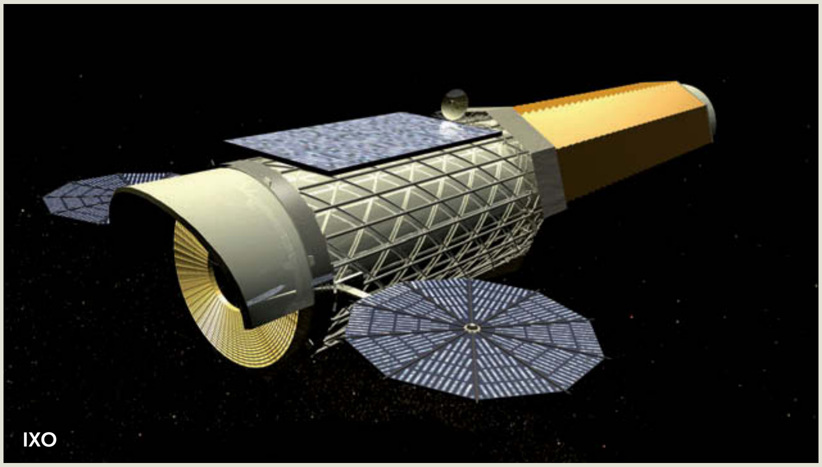
"It was not as much as we hoped for, by at least a factor of three," counters Marc Postman (Space Telescope Science Institute), who had been part of a team that had proposed several different large optical/ultraviolet space telescopes to replace Hubble. He adds, however, that, "It's unclear any other decadal committee could have come up with anything dramatically different, considering the extreme budget limitations the committee was operating under."

WHO PAYS FOR TELESCOPES?

Space-borne U.S. observatories and planetary missions are mostly funded through NASA and space agencies from other nations. Ground-based U.S. observatories are mostly funded by the National Science Foundation, universities, and various public and private sources. The U.S. Department of Energy also contributes to space- and ground-based astronomical projects.

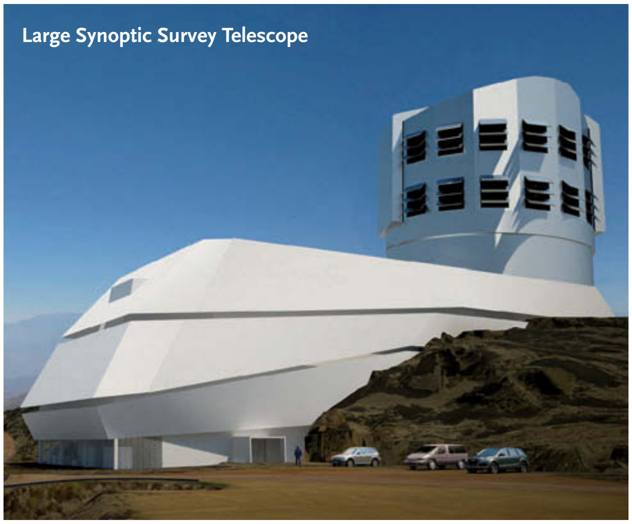
The Future?

In fact, every scientist commenting on the decadal survey, both pro and con, recognized the budget issue as the central constraint on all of the committee's recommendations. And the biggest constraint of all was the state of JWST, several years behind schedule and many times over budget. A recent report points out that JWST will need an additional $1.5 billion (raising its total cost to at least $6.5 billion), and that the launch will slip to September 2015 at the earliest (last month's issue, page 20). "This decadal survey was between a rock and a hard place because of the excesses of our past," says Kulkarni. "There's not much money because of unconstrained out-

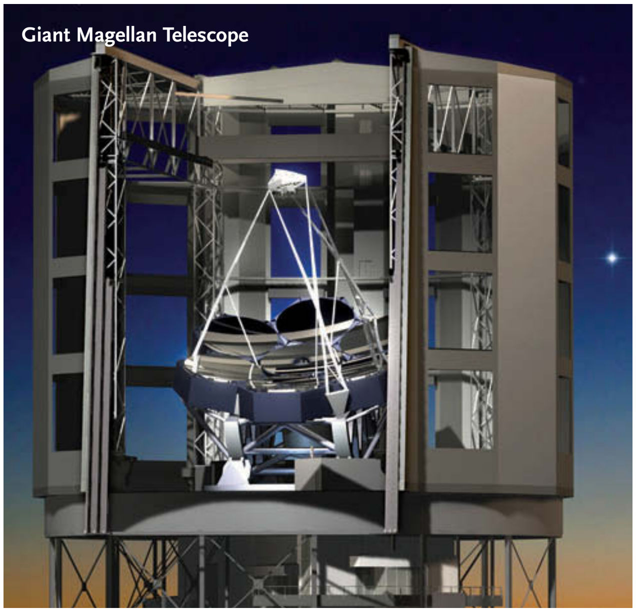


NASA

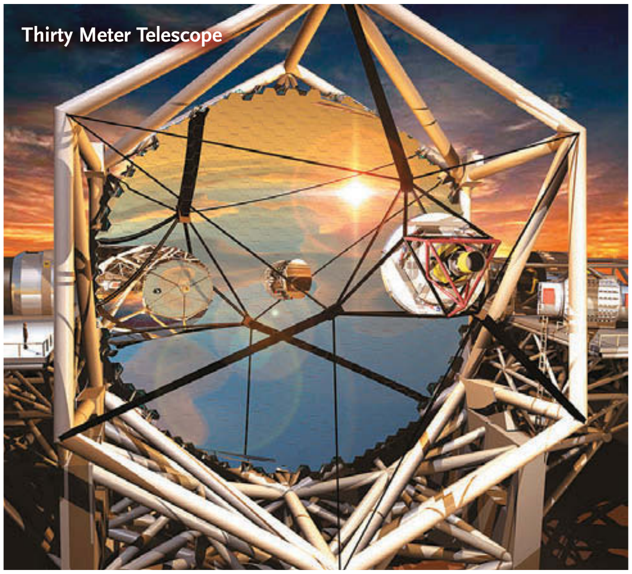
The decadal survey committee gave high rankings to the Laser Interferometer Space Antenna *(left)* and the International X-ray Observatory *(right)* because of their tremendous scientific potential. But because these missions ranked behind WFIRST and will each cost several billion dollars (but less than JWST), it's very unlikely that either mission will be funded at a level that will enable it to be launched in the coming decade. LISA could detect gravitational waves from numerous sources, including merging supermassive black holes. IXO would build upon the achievements of Chandra and XMM-Newton, with the ability, for example, to test Einstein's general theory of relativity in the vicinity of black holes. Both missions include significant international partnerships, particularly with the European Space Agency, to reduce costs for NASA.



LSST CORPORATION



GIANT MAGELLAN TELESCOPE / GMTO CORPORATION



TMT OBSERVATORY CORPORATION

of-control missions like Webb. Webb is breaking the bank in this decade."

For example, until JWST is launched, it will be impossible for NASA to begin serious funding of WFIRST. Though the agency is immediately allocating funds for WFIRST's initial design studies, Weiler says, "In terms of real funding, when you start hiring hundreds of engineers and cutting metal, that won't be available until JWST launches."

Due to the shortage of funds, many scientists are questioning whether WFIRST should even be built. As one astronomer (who wished to remain anonymous) noted, "I've heard, second hand, that NASA headquarters has said it will drag its feet, stating a possible WFIRST launch date of 2023, 2024, 2025 . . . hoping it goes away."

Weiler vehemently disagrees, saying, "Our playbook is the National Academy decadal surveys. I am not going to differ from them. It is the most senior respected scientific body on Earth."

Nonetheless, the budget difficulties are further compounded by the significant changes to Congress following the 2010 elections. The federal government's $13.8 trillion debt, and the likely shift of Congress toward tighter fiscal policy, suggest that finding funds for the decadal survey's recommendations is going to be difficult, even with the committee's effort to base its recommendations on a relatively flat federal astrophysics budget. As Weiler notes, "Tell me which way Congress is going to go. Will the new Congress like NASA or will it not like NASA?"

Space-based astronomy faces a perilous future. The recommended high-cost space projects all require more money than might be available. Worse, as the decadal survey noted, "With the possible exceptions of the JWST and SOFIA, none of the missions operating or starting today are expected to be operational at the end of the decade." Thus, if Congress decides not to fund any of the high-cost missions proposed by the 2010 survey, there might be hardly any large space-based NASA telescopes in operation by 2020.

Compounding these issues is the lack of any proposed compelling space-based project proposed by the decadal

BRIGHT FUTURE The decadal survey committee ranked the Large Synoptic Survey Telescope *(top)* as the highest priority for large ground-based telescopes. Given its affordable cost and multiple sources of funding, it will almost certainly be conducting its unprecedented deep all-sky survey before 2020. The decadal survey committee also gave high priority to the construction of a giant ground-based telescope. This probably means that either the Giant Magellan Telescope *(center)* or the Thirty Meter Telescope *(bottom)* will receive funding from the National Science Foundation, and both are already receiving financial support from a variety of public and private sources. One or both of these observatories are likely to be built in the next 10 years. LSST, GMT, and TMT will all have the potential to make revolutionary discoveries in many different fields of astronomy.

survey that can capture the imagination of both the public and Congress, such as a bigger and more advanced optical telescope to replace Hubble, or a space telescope that could image nearby exoplanets. As interesting and exciting as WFIRST might be, it lacks the sex appeal of a space-based optical telescope, which produces images comparable to what our own eyes would see, or a telescope that will take the first images of an Earthlike planet. Convincing Congress and the public to fund WFIRST to the tune of $1.6 billion is not going to be easy.

Fortunately, the future of ground-based astronomy seems less dire. Other nations as well as private sources are already funding the construction of the recommended ground-based telescopes such as LSST and the various giant segmented telescopes, so the overall costs are significantly lower. Moreover, their gigantic nature, scanning the heavens quickly and frequently in optical wavelengths, makes them something the public can more easily get excited about.

At the August 13th press conference announcing the release of the 2010 survey, committee member Neil deGrasse Tyson (Hayden Planetarium) summed up the importance of all of astronomy's decadal surveys: "What a luxury that we can prioritize science, knowing that the fruits of our discoveries, if and when they arrive, will be page one stories in the press." He then added, "We as a community invented this concept of the decadal survey. It has been a remarkable exercise in consensus building."

Whether such consensus building, however, is going to lead to bigger and better telescopes in the coming decade remains at this moment an unanswered question. ✦

---

*Contributing editor **Robert Zimmerman** covers the world of science and space from his website, behindtheblack.com.*

A Design for the Decade

The Hubble Space Telescope. The Spitzer Space Telescope. The Chandra X-ray Observatory. These majestic observatories and many others have thrilled us with their iconic images while providing data for decades of discoveries. But how do the dreams of new missions and telescopes get transformed into reality?

On a national scale, the road often begins with the Astronomy and Astrophysics Decadal Survey. I was privileged to serve on Astro2010, whose *New Worlds, New Horizons* committee report is highlighted in the accompanying article. With unprecedented community input, we were guided by the visions of astronomers nationwide. We decided on the most compelling science, and selected projects to enable research under the broad themes of early universe, exoplanets, and fundamental physics.

Unlike previous surveys, we had agency budget guidelines and independent cost and risk assessments, so our recommended programs would not suffer huge cost overruns. Our choices were exceedingly difficult, and necessarily left much of the community disappointed, because great ideas exceeded predicted funding by a factor of 10. Exciting but technologically immature projects had high projected costs because of uncertainties in achieving timely completion. For many of these concepts, we recommended aggressive research in this decade that might lead to missions in the following decade. For example, our highest-ranked medium-scale space priority is an integrated plan of technology development for exoplanet detection and characterization, to prepare for a future large telescope targeting Earth-like planets.

Our report is a guideline for Congress, funding agencies, and astronomers. We recommend a balance of small, medium, and large programs. The top-ranked large programs are a Wide Field Infrared Space Telescope (WFIRST) and a ground-based optical Large Synoptic Survey Telescope (LSST), which both have broad astronomy goals. We also recommend investment in a 30-meter telescope. These were selected to build on observations by the James Webb Space Telescope (JWST). If Congressional budgets are austere, we present streamlined priorities. We have built-in tripwires too: for example, the LISA gravitational-wave mission is contingent on a successful pathfinder mission. We also recommend forming an advisory committee to consider redirections in the event of unforeseen circumstances, such as further delays to JWST.

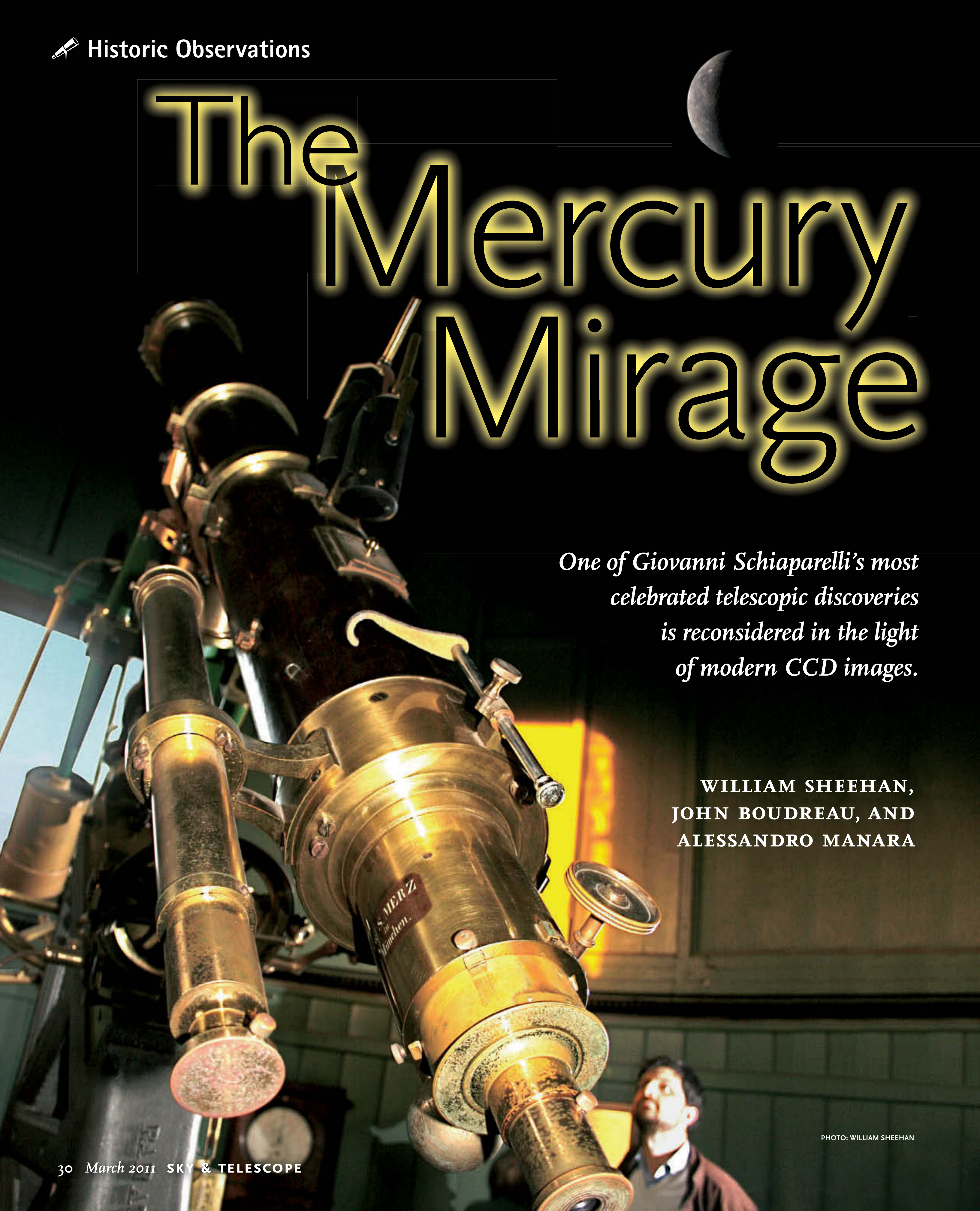
Numerous smaller projects were given equal priority to large projects. We call for nearly annual launches of low-cost but high-science-return satellites like WMAP and Swift, and suborbital launches, which provide a rapid return on data while helping to train the next generation of instrumentalists. The top-ranked medium ground-based project is CCAT, a 25-meter submillimeter wide-field telescope to complement ALMA, which is currently under construction. We also recommend funding other competitively selected projects, which may include adaptive optics, pathfinders for the Square Kilometer Array, and high-energy detectors; plus continued support of national observatories and basic research, including observations, theory, computation, and laboratory astrophysics. We also discuss how astronomers are educated and trained, where they are employed, how computation and data are handled, and how astronomy benefits society.

After two years of work on the Decadal Survey committee, I'm optimistic that we have laid the groundwork for a tremendously exciting decade of new worlds and new horizons.

---

*Decadal survey committee member **Debra Meloy Elmegreen** is President of the American Astronomical Society and Maria Mitchell Professor of Astronomy at Vassar College.*

The Mercury Mirage



One of Giovanni Schiaparelli's most celebrated telescopic discoveries is reconsidered in the light of modern CCD images.

WILLIAM SHEEHAN, JOHN BOUDREAU, AND ALESSANDRO MANARA

PHOTO: WILLIAM SHEEHAN

Italian astronomer Giovanni Virginio Schiaparelli was arguably the most skillful visual planetary observer of the 19th century. Born in Savigliano in 1835, he trained under Johann Encke at the Berlin Observatory and under Friedrich Georg Wilhelm von Struve at the Pulkovo Observatory in Russia. But in 1860 Schiaparelli returned to Italy and spent his remaining 40-year career at the Brera Observatory in Milan.

Although his most important work was demonstrating the link between meteor swarms and the orbits of periodic comets, he is best remembered for his studies of Mars, which began during the grand opposition of 1877. Using an 8-inch Merz refractor mounted within a cupola on Brera's roof, Schiaparelli drew a new map on which he introduced the system of nomenclature that is the basis of the one still used today. He also introduced the groovelike markings he called *canali* (later "canals"), which would set off a furor about the possibility of intelligent life on the Red Planet.

Schiaparelli also devoted a great deal of time to Mercury. His meticulous observing logbooks are carefully preserved in the Brera Observatory's library. As part of a reevaluation of Schiaparelli's Mercury work, Brera astronomer Alessandro Manara made copies of his drawings; ALPO transit recorder John Westfall computed central meridians and other data; and William Sheehan communicated this data to amateur CCD imager John Boudreau, who imaged the planet under circumstances similar to those of Schiaparelli's observations. The result is a comprehensive reassessment of what Schiaparelli thought he saw — and why.


WILLIAM SHEEHAN

BRERA OBSERVATORY **The cupola of Milan's Brera Observatory appears in the center. Schiaparelli lived just a few blocks away.**

A New Challenge

Before Schiaparelli, Mercury observers had struggled in vain to discern any surface details during twilight, when the planet's paltry image was vexed by rushing air currents. German amateur Johann Hieronymus Schroeter, using a large reflector at his observatory at Lilienthal in 1800, published a rotation period of about 24 hours based on his reported sighting of an extremely high mountain.

There were no further notable results until 1870. That year, British observers Warren De la Rue and William Huggins reported "markings, like the lunar craters, of a dazzling whiteness and seen as through a veil of mist." About the same time German photometric astronomer Karl Zöllner suggested that Mercury, based on its low albedo, must be a body "the surface condition of which must be nearly the same as that of our Moon," and furthermore "probably does not hold an appreciable atmosphere."

De la Rue and Huggins's observations appeared in an obscure astronomical journal, so few paid attention. Zöllner's work was published in a journal read only by physicists. Being a traditionalist about scientific disciplines, Schiaparelli believed that astronomers should stick to astronomy and leave physics (spectroscopy and photometry) to physicists, so he was unsympathetic to the approach and probably didn't keep up with the physics literature. Unfortunately, Schiaparelli failed to absorb this important clue that Mercury was a world without air or clouds. This would prove to be an unfortunate oversight.

In June 1881 Schiaparelli began testing a new approach to studying Mercury. Instead of observing in the unfavorable twilight periods as previous observers had done, he used the equatorial mount's setting circles to flush the planet from its hiding place in the midday sky. Though his initial test proved promising, he decided to wait until January 1882 — the depth of winter, when conditions in Milan were often superb for planetary viewing — to

MERZ REFRACTOR **In 1882–83 Schiaparelli observed Mercury with this 8-inch Merz refractor at the Brera Observatory in Milan. The refractor has been refurbished and restored.**

GIOVANNI SCHIAPARELLI This portrait of Schiaparelli was created in the 1880s, around the time he was diligently observing Mercury. The Italian astronomer was one of the great observers of his day.

launch a full-scale investigation.

The planet was then east of the Sun, and at 200×, Schiaparelli found delicate but definite markings. He saw bands and bright spots but "vague and diffused ... from the want of fixity of the edges." His sketches and notes of these ambiguous markings reveal occasional exclamations such as "momento stupendo," but more often his notes contain expressions of frustration at the difficulty of the observations and dissatisfaction with his sketches.

The Figure "5"

Almost at the start, Schiaparelli had a break; the features seem to sort into a pattern resembling the numeral 5. By keeping the planet in the eyepiece for several hours at a time, and noting no change in the disposition of these features, he showed that the rotation period must be much longer than 24 hours. But just how long?

Following the planet around the Sun and back again, he observed it east of the Sun in May. The atmosphere was now less forgiving than it had been in the winter (at times, the cupola containing the Merz refractor was "infernally hot"), and he made only half as many drawings as in January and February. Still, he saw — or thought he saw — the figure 5 again. He now had a perceptual bias that would mold the rest of his investigation.

In fact, our study of Schiaparelli's logbooks shows that he was actually examining Mercury's opposite hemisphere. The central meridian during his May–June observations was centered on or about longitude 260°, give or take 10°. In January–February, it was on or about longitude 70°.

Schiaparelli kept Mercury under surveillance throughout the summer. In early August 1882, he heroically chased it right up to superior conjunction, to within only 3½° of the Sun. These observations seared his eyeball, and led to a "weakening" of his eyesight that forced an early retirement from visual observing in the 1890s and perhaps contributed to complete blindness in his final year of life (he died in 1910).

When Schiaparelli seemed to recover the figure 5 around Mercury's next great elongation east of the Sun at the end of September, his ideas finally converged on some definite conclusions. No doubt in the back of his mind was the evolution of the Earth–Moon system, recently treated in an 1877 publication by British astronomer George Howard Darwin (son of the famous naturalist). Darwin had shown how tides raised by Earth on the primordial Moon had gradually slowed the Moon's spin, until it turned on its axis in the same period that it takes to complete one orbit around Earth.

Schiaparelli had every reason to suppose that tidal friction with the Sun had also produced a "captured rotation" for Mercury, locking its day into the period of its year — 87.9693 days. The fact that the planet seemed to show the same face each time it came around the Sun similarly locked in his thinking, and by October 30, 1882, Schiaparelli announced to his favorite correspondent, François

DRAWINGS: BRERA ASTRONOMICAL OBSERVATORY (2)

CCD IMAGES: JOHN BOUDREAU (2)

MERCURY COMPARED Schiaparelli's Mercury drawings *(top left and bottom left)* are compared to John Boudreau's CCD images *(top right and bottom right)*. *Top:* This comparison shows Mercury at a central meridian of about 87°. A figure resembling the numeral 5 appears in both pictures, suggesting that Schiaparelli was indeed seeing actual surface features at the limits of his perception. *Bottom:* In the drawing at left, at a central meridian of 237°, Schiaparelli drew a 5 that has no corresponding feature in Boudreau's image taken at almost exactly the same central meridian. Schiaparelli may have been filling in detail with his imagination, based on his erroneous assumption that Mercury's rotation period is the same as its orbital period. South is up in all images.

Terby at the University of Louvain in Belgium, a tentative result in Latin hexameters. What he wrote, in English translation, was:

> *Mercury on its axis turns like the Moon:*
> *One side has lasting day, the other night;*
> *One side in everlasting fire doth swoon,*
> *While th'other hides forever from the light.*

In fact, Schiaparelli had not yet published his result. Though already by the end of 1883 Schiaparelli had followed Mercury through seven synodic periods and amassed an archive of 150 drawings, his health broke down — probably in part from overwork. By the time he recovered, he awaited the delivery of a new 18-inch Merz & Mahler refractor, and wanted to confirm his observations with the larger instrument.

Installed in 1886, he observed three more years (though not with the same intensity as in 1882–83), and finally, in November 1889, published "On the Rotation of Mercury." This classic monograph includes his celebrated map of the supposed daylight side of the planet. On December 8, 1889, he gave a lecture in the Quirinal Palace in Rome before the king and queen of Italy.

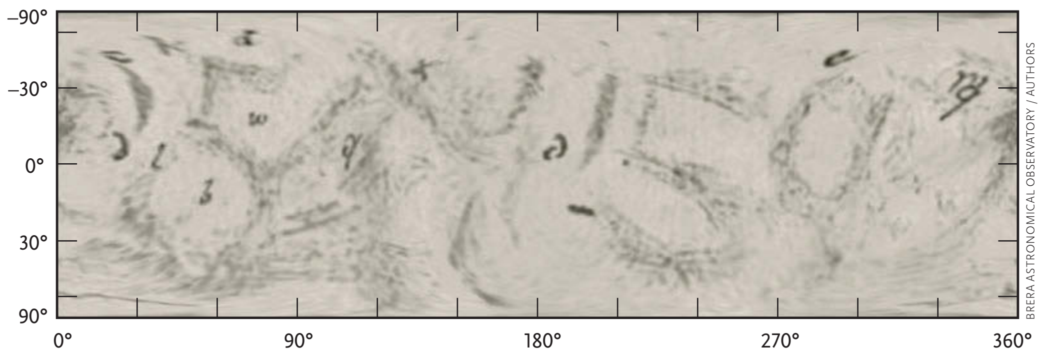
His main conclusion: "Mercury revolves around the Sun in a manner similar to that in which the Moon revolves around Earth." He claimed to have established the identity of the rotation and revolution periods to 1 part in 1,000. Later astronomers, including E. M. Antoniadi and Audouin Dollfus, concurred. In fact, right up until 1965, there was probably no result in planetary astronomy more secure than Mercury's rotation period. The finding that Antoniadi once called "the most beautiful of all the Italian astronomer's telescopic discoveries" appeared to be established beyond reasonable doubt.

JOHN BOUDREAU

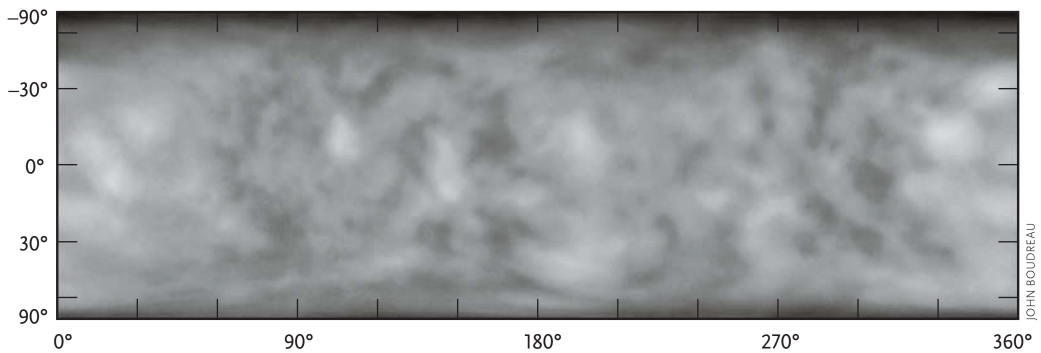
MERCURY IMAGER John Boudreau, a leading amateur planetary CCD imager, poses with his C11 telescope at his home observatory in Saugus, Massachusetts.

Fudge Factor

Then, in 1965, astronomers absorbed two tremendous shocks. First, Mariner 4 flew past Mars, sweeping away the legendary canals and showing the planet instead to be a stark world of ubiquitous craters. Meanwhile, radio astronomers Gordon Pettengill and Rolf Dyce, using the 305-meter antenna at Arecibo, Puerto Rico, proved that Mercury's rotation period is 58.65 days, not 87.9693 days. Italian dynamicist Giuseppe Colombo realized soon



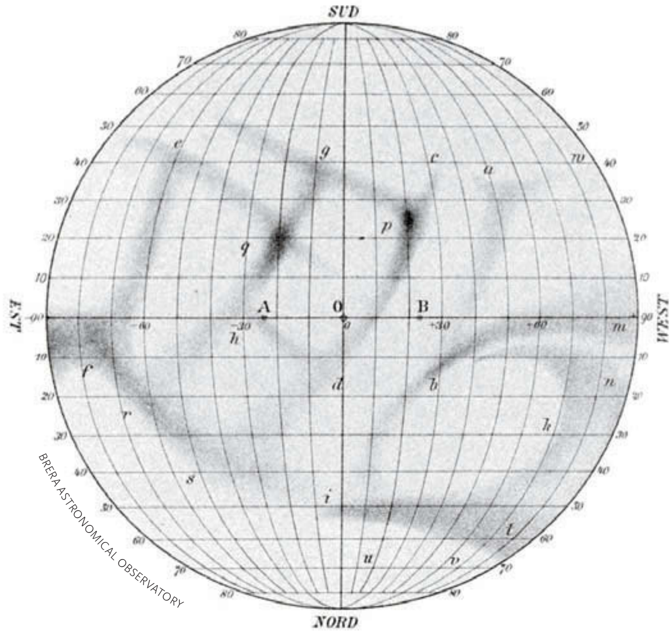
BRERA ASTRONOMICAL OBSERVATORY / AUTHORS



JOHN BOUDREAU

CYLINDRICAL PROJECTIONS *Top:* The authors created this cylindrical projection of Mercury from some of Schiaparelli's best drawings, corrected for the planet's 58.65-day rotation period. *Bottom:* Coauthor John Boudreau has shot a series of CCD images of Mercury, and assembled them into this projection with the same longitudinal projection as the Schiaparelli map. Note that the figure of 5 is barely visible around 60° to 90°. South is up in both images.

For more information on observing Mercury, visit the Mercury Section at http://alpo-astronomy.org.



BRERA ASTRONOMICAL OBSERVATORY

MERCURY MAP **Schiaparelli drew this map of Mercury's supposed day-lit hemisphere in 1889, years after his most active period of observing the innermost planet.**

afterward that the rotation period was exactly two-thirds of a Mercury year.

Stock in visual observations dropped to unprecedented lows. For a time, it seemed that Schiaparelli and other observers might have been mapping nonexistent illusions. Only gradually did things begin to make more sense.

In fact, Mercury's surface markings are exasperatingly indefinite and vague, consisting of brightish patches (which NASA's Mariner 10 and Messenger spacecraft have shown to be rayed craters) scattered against a halftone background. Schiaparelli himself had mentioned the "want of fixity of the edges" that left "room for a certain choice" in their depiction. Not only that, but the appearance of features on Mercury is greatly affected by observing geometry relative to Earth, the local altitude of the Sun, and the phase. Even if one imagines that one is making out a familiar face at different seasons of observation, that face may be disguised, like a Venetian masquerader at carnival.

SEE MERCURY

March 2011 is an excellent month to observe Mercury in the evening sky due to its favorable elongation from the Sun (see page 48). Can you discern any subtle surface markings on the planet's surface?

Schiaparelli's logbooks show that his recorded features shifted from day to day, but Schiaparelli thought he was seeing an effect of librations similar to but even more extreme than those of the Moon. Even making allowance for such effects, he could not reconcile all the observations; sometimes markings that should have been present were fragmentary or missing. As early as November 1882, Schiaparelli informed British amateur and fellow Mercury observer W. F. Denning that he found the markings "extremely variable," and sometimes "partially or totally obscured." That gave him a convenient fudge factor that kept him from realizing that different parts of the planet were drifting into view. Instead, Schiaparelli wrongly surmised the existence of a Mercurial atmosphere whose clouds were "more frequent and obliterating" than those of Mars.

Autosuggestion

Since 2007 John Boudreau has made hundreds of CCD images of Mercury (*S&T:* October 2009, page 70), and discovered many images in which conditions match those when Schiaparelli was sketching the planet in the 1880s. For example, in March–April 2010 the planet's eastern apparition closely duplicated the basic conditions of Schiaparelli's early observations in 1882. A comparison of images with sketches shows some cases of striking agreement. Clearly, Schiaparelli was seeing real features, and recording them with considerable skill. He did as well as possible given the difficulty of his project.

But the figure 5 was the *idee fixe* that led him astray. Look at the cylindrical projection of Mercury's features. Among such ambiguous markings, it was easy to eke a bit from here, and a bit from there, to conform to his expectation. Once he assumed the effects of librations and clouds, he could explain away all discrepancies. William Sheehan has written of this process: "Once a definite expectation is established, it is inevitable that one will see something of what one expects; this reinforces and refines one's expectations in a continuing process until finally one is seeing an exact and detailed — but ultimately fictitious — picture. Schiaparelli's work is a remarkable case study in autosuggestion."

The case of Mercury's rotation serves as a classic reminder of the fallibility — but ultimately the self-correcting nature — that is the greatness of science. We may be tempted to condescend to the visual observers who struggled against great odds, and ended up mired in mirages and illusions. But as English poet Alexander Pope wrote,

> *We think our fathers fools; so wise we grow,*
> *Our wiser sons may someday think us so.*

How many of our own cherished ideas will prove to be similar cases of autosuggestion? ✦

Contributing editor ***William Sheehan*** *is a psychiatrist and astronomical historian based in Willmar, Minnesota. Massachusetts amateur and avid ALPO member* ***John Boudreau*** *has specialized in the CCD imaging of Mercury since 2007. Brera Observatory astronomer* ***Alessandro Manara*** *studies the physics and dynamics of minor bodies and the history of astronomy.*

It's a Duesy

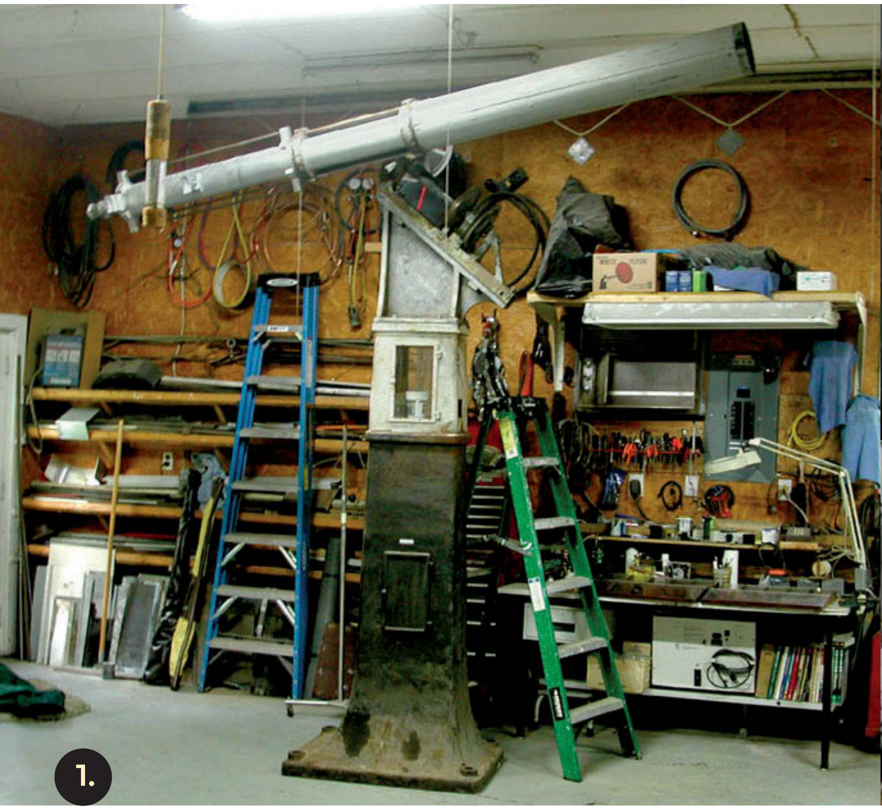
Here's the tale of how a nearly forgotten telescope became the showpiece of an amateur astronomy club in Missouri.

Mike Boessen

WE'VE ALL HEARD stories about some guy walking in the woods and finding a 1936 Duesenberg rusting away in a long-forgotten tin shed, and the automobile turns out to be one of only a handful that were ever made. You never think something like that is going to happen to you.

About 2002, after my fourth back surgery, I arrived at the conclusion that I was no longer going to play golf. Casting about for something to do with my spare time, I joined the local astronomy club, the Central Missouri Amateur Astronomers (CMAA). My first star party was a Messier marathon at a small piece of land we call Wildhaven. Located on the property are two small, unassuming buildings.

As the evening wore on and the cold set in, it was



ALL PHOTOS COURTESY OF THE AUTHOR

1. After more than a century of service, a well-traveled 7½-inch Merz & Mahler refractor was retired in the early 1960s and put into storage at the University of Missouri. Upon learning that the tube and mount were going to be scrapped in the 1980s, the Central Missouri Amateur Astronomers (CMAA) held a fund-raising campaign and acquired the instrument. A planned restoration project stalled, however, and the scope sat mostly neglected in a shed at the club's dark-sky property. Early last year, with the club's endorsement, the author moved the instrument to his home workshop (shown here) and began a lengthy restoration project. 2 & 3. Close-ups reveal the general poor condition of the mount's heavy brass castings and the peeling paint that covered them.

announced that coffee and chili were available in the "large" building. I walked through the front door, and there was my Duesenberg. I couldn't believe my eyes. Standing before me, 11 feet tall, 12 feet long, and with an 8-inch aperture, was the biggest refractor I had ever seen. It was covered in dust and had been painted battleship gray with a brush, but it still retained the austere dignity of my maternal grandfather. A brown paper bag had served as its dew cap, and the pier was a condo for rodents. I was struck with a mixture of awe and sadness, and not knowing it consciously at the time, a strange romance had been kindled.

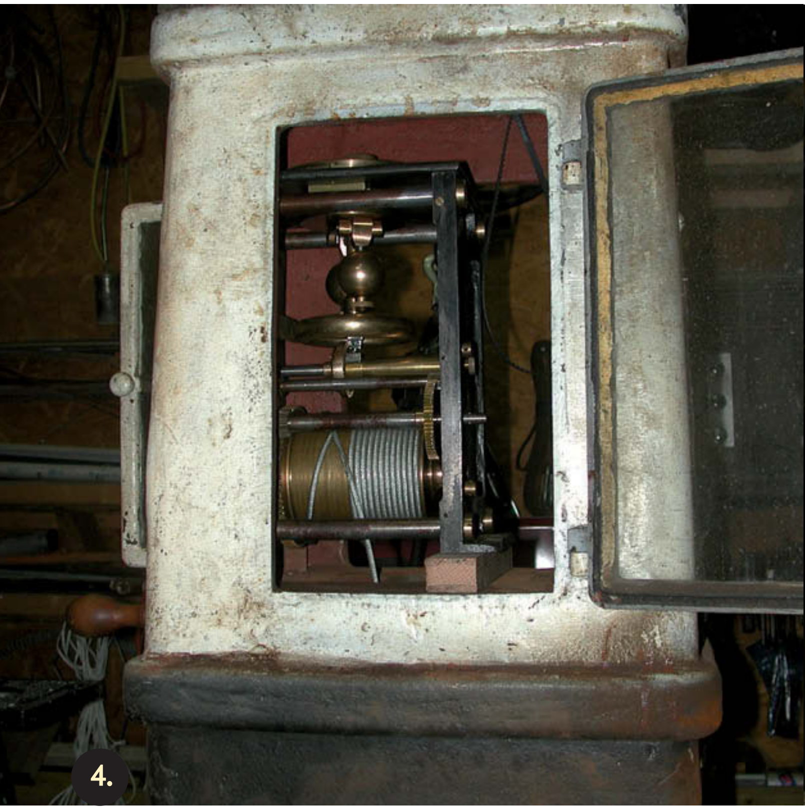
The Road to Missouri

Rewind to post-Renaissance Germany, when astronomy was finally recovering from the repression of the Middle Ages, and real science was advancing our knowledge of the universe. In the 1820s the field was blessed with a true genius named Joseph von Fraunhofer, the 11th child of Franz Xaver Fraunhofer, a master glazier in Munich, Germany. When tragedy befell his family life, young Fraunhofer was apprenticed to a glass cutter. Later, after setting out on his own, he joined the optical shop of a Munich instrument company headed by Joseph von Utzschneider. Fraunhofer excelled, and by 1809 he was managing the optical shop, eventually becoming a business partner with Utzschneider.

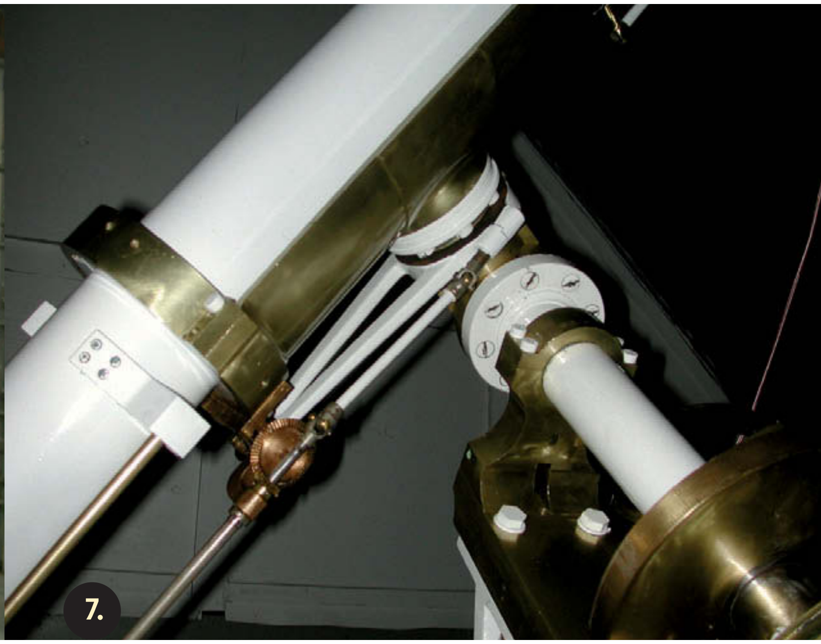
When Fraunhofer joined the firm, lens making was a wide open field. Telescope objectives at this point, while far improved from the days of Galileo, were still fairly rudimentary. Nevertheless, before long Utzschneider and Fraunhofer established themselves as the world's premier manufacturers of optical glass. Also, Fraunhofer developed the first equatorial mount in their factory. That design is used with little change to this very day and is still referred to as a German equatorial mount.

Following Fraunhofer's untimely death in 1826 at age 39, Utzschneider ran the company

Fraunhofer



4. Since the original falling-weight clock drive for the mount had long ago disappeared, the author substituted a drive of similar vintage, which had been previously restored by another CMAA club member. Nevertheless, this drive's manufacturer remains a mystery, and the author welcomes any insight that readers can offer. 5. While the scope's original wooden pier had been replaced by a Warner & Swasey cast-iron pier and wedge in the early 20th century, the mount retains the equatorial head made by Merz & Mahler in the late 1840s. The scope's original objective is on display at the University of Missouri, having been replaced in the current scope with an 8-inch doublet made by a club member in the 1960s.



6. Suspended by wires in the author's workshop, cleaned and polished brass pieces of the mount dry after being coated with a protective layer of clear automotive urethane. 7. A close-up view shows the workings of the mount's declination clamp and tangent-arm slow-motion control, which are both operated by concentric shafts extending to the eyepiece end of the tube. The locking shaft rides inside the hollow shaft that drives the bevel gear for the tangent-arm drive screw.

with Georg Merz, who had worked with Fraunhofer since 1808. Merz, too, was a genius and he singlehandedly perfected the manufacture of optical glass to the point where he could produce instruments with apertures of 10 or more inches, tripling the light-gathering potential of most existing telescopes.

Merz and the wealthy businessman Josef Mahler bought the company in 1839. They achieved the "mass production" of telescopes of unparalleled quality and performance, bringing the heavens to the doorstep of any institution of significant means. Two notable Merz & Mahler refractors in the United States are the 11-inch at Cincinnati Observatory, and a true monster of its day, the 15-inch at Harvard College Observatory.

About 1847 Joseph Winlock of Shelby College in Tennessee contracted Merz & Mahler, ordering a 7½-inch equatorial refractor for the school. (Winlock eventually become the third director of Harvard Observatory.) In the mid-1850s the instrument was moved to Cambridge, Massachusetts, where it was used extensively by Winlock and astronomer Benjamin A. Gould.

After the scope was returned to Shelby College, it was used by Winlock to observe the 1869 total solar eclipse. America's famous telescope makers George and Alvan Clark were part of that effort, and insured that the Shelby refractor was in top working order for the once-in-a-lifetime event. In 1879 the telescope was acquired by the rapidly growing University of Missouri, most of the cost personally covered by university president S.S. Laws, for whom the university's current observatory is named.

By the early 1900s, the refractor's wooden pier was in disrepair and another prominent American telescope company, Warner & Swasey, was contracted to provide a cast-iron pier and wedge. The instrument, still with its original wooden tube, was also outfitted for photography and photometry. In the early 1950s, the university's metal shop replaced the wooden tube with a modern one made of aluminum and steel.

In the early 1960s the university constructed a new physics building, which included a metal dome and modern 16-inch reflector. The old observatory was abandoned and later demolished. My "Duesy" was put into storage in the new physics building, and then, in the early 1980s, was slated to be scrapped. Fortunately, university astronomer Charles Peterson contacted the CMAA, and the club had a fund-raising campaign that saved the historic refractor. In the mid-1990s a building was constructed at the club's Wildhaven site and the instrument was moved there, but the planned restoration project languished.

Fast Forward to the Present

At the CMAA's April 2010 meeting, I broached the issue of the neglected telescope. After much deliberation, we decided that our small club didn't have the resources to make the necessary repairs to the building, much less restore the old scope.

8. The freshly painted cast-iron pier awaits final assembly of the telescope. 9. With the help of club members and several colleagues from his workplace, the author repaired and updated a roll-off-roof observatory at the club's dark-sky observing site and then installed the restored refractor. First light took place at the end of August last year, with the scope providing "spectacular" views of Jupiter and the Moon. The CMAA is planning to use the scope for regularly scheduled public observing nights in the near future.

I wasn't content with the thought of the telescope's continuing decline. With the support of the club's president, Val German, I loaded my truck with tools, hitched a trailer, and assisted by several club members, dismantled the scope and moved it to a workshop behind my house.

The restoration work was incredibly challenging. There were few manufacturing standards at the time the scope was made. Each company made its own screws and bolts with different diameters and thread pitches. Just restoring a damaged bolt could take hours.

Val and his brother Farrell helped me remove the horrible paint from the scope's beautiful brass castings, and they also helped with the subsequent cleaning and polishing. I spent several weeks scraping, sandblasting, and wire brushing the iron, steel, and aluminum parts. These were then dressed it in a beautiful coat of snow-white paint, and the gleaming brass was protected with clear automotive urethane. When I reassembled the scope in the workshop and stood back, tears came to my eyes. She was, indeed, a beauty.

Only two hurdles remained. The university has the original Merz & Mahler objective and lens cell in a display case in the physics building. But the club had an 8-inch doublet made in the 1960s by the late Monty Gruwit, a former member. Val helped me modify the tube for the new lens, and I then modified the lens cell to fit the tube.

The other hurdle involved the scope's original clockwork mechanism, which has been lost to history. Some years ago a former club member, John Reed, showed an amazing clockwork mechanism of appropriate vintage at a club meeting. Val contacted Reed, who is now living in the Boston area, and he graciously donated the clockwork for our project. Reed had beautifully restored the mechanism, but it had worn-out gears that were impossible to replace. I spent weeks with a loupe stuck in my eye, filing gear teeth by hand. We don't know who manufactured this clockwork, and we welcome any insight that *Sky & Telescope* readers can offer.

With more help from Val, Farrell, and several work colleagues, I repaired the original building at Wildhaven, painted it, and installed electricity and lights. After overcoming a few optical and mechanical hurdles, the restored scope had a new first light last August 27th. We first turned the refractor to Vega, and followed with Jupiter and the Moon. The views were spectacular.

The club is planning a grand opening for the public, and eventually we'll have regularly scheduled open nights. My joy could not be greater, nor my satisfaction more complete, knowing that this grand old pre-Civil War telescope will once again bring the heavens down to us humble humans. It truly is a beautiful instrument, and in my mind I can hear my grandfather exclaim: "It's a Duesy!" ✦

__Mike Boessen__ is an X-ray machine repairman at Boone Hospital Center in Columbia, Missouri. He can be reached at mboessen@bjc.org.

New Product Showcase

▶ **IPOD GO-TO** Now you can use your iPhone, iPad, or iPod Touch as a powerful telescope controller thanks to SkyWire ($79) from Southern Stars. This adapter adds a 30-inch cable and RS-232 port to your Apple device, allowing you to control any telescope that accepts a serial connection. SkyWire works with the Southern Stars *SkySafari* planetarium app (formerly *SkyVoyager*), turning your smart device into a go-to controller with an interactive sky chart and tens of thousands of objects accessible with just a few taps on the screen. SkyWire is an Apple-approved accessory that requires no modification to your Apple device. Some telescopes may require an additional cable to adapt SkyWire's standard DB9 connector.

SOUTHERN STARS

Southern Stars
210 Fell St. #4, San Francisco, CA 94102;
415-671-6251; www.southernstars.com

S&T: DENNIS DI CICCO

DIGITAL SCT FOCUSER William Optics has incorporated an innovative digital readout into its popular dual-speed 2-inch Schmidt-Cassegrain focuser. The new Digital Display Gauge (DDG) SCT Focuser ($248) is designed to thread onto the rear cell of most commercial Schmidt-Cassegrain and Maksutov-Cassegrain telescopes. The DDG and 10-to-1 speed reduction allows precise, repeatable focus, which is displayed with an absolute reading of 0.01 millimeter. A built-in dial thermometer enables you to monitor temperature throughout the evening. The focuser, which can be rotated 360°, has two locking screws for securing the focus position when heavy cameras and accessories are attached. A 1¼-inch adapter is included with purchase.

William Optics
30F, No. 29-5, Sec. 2, Zhongzheng E. Road
Danshui, Taipei 251, Taiwan
+886-2-2809-3188; www.williamoptics.com

▼ **8300 FROM THE U.K.** Starlight Xpress joins the "8-megapixel club" with its new SXVR-H18 CCD camera ($2,460). This model features Kodak's 8.3-megapixel KAF 8300M sensor with 5.4-micron-square pixels in an array measuring 18 × 13½ millimeters. The camera housing keeps with the manufacturer's signature cylindrical design and is 70 mm (2.76 inches) in diameter and 75 mm long. It features a mechanical shutter and regulated, two-stage thermoelectric cooling down to 40° C below ambient temperature. Full-frame exposures download in approximately 4½ seconds via a USB 2.0 computer interface. The SXVR-H18 includes a proprietary autoguider output as well as a 42 mm "T2" threaded aperture. Additional information is available on the company's website.

STARLIGHT XPRESS

Starlight Xpress
The Office
Foxley Green Farm, Ascot Rd.,
Holyport, Berkshire
SL6 3LA, United Kingdom
+44-0-1628-777126
www.starlight-xpress.co.uk

New Product Showcase is a reader service featuring innovative equipment and software of interest to amateur astronomers. The descriptions are based largely on information supplied by the manufacturers or distributors. *Sky & Telescope* assumes no responsibility for the accuracy of vendors' statements. For further information, contact the manufacturer or distributor. Announcements should be sent to nps@SkyandTelescope.com. Not all announcements can be listed.

Treasures of Puppis & Hydra

Many lesser-known treats adorn these constellations.

Our centerfold map on the following pages shows the starry sky at 8^h sidereal time, when the 8-hour line of right ascension coincides with the sky's central meridian. We can call this the Gemini Hour, after the constellation that's just southwest of the zenith now.

This month, let's bypass bright Gemini itself and delve for some dimmer but delightful objects near the meridian and a little east of it. Among these wonders is one that's tremendously too faint for us to see — until a half century from now, when the object next approaches Earth. I'm referring to Halley's Comet, our planet's most famous visitor, which 25 years ago this month of March was at its best during its most recent return.

AKIRA FUJII

Halley's Comet was bright in 1986, as shown above. It's almost undetectable now — a dim, distant, icy ball resting up in Hydra for its next pass through the inner solar system in 2062.

Clusters of Puppis. Right on the southern horizon is Puppis, the poop deck of the defunct ship Argo. This constellation has no extremely bright stars, but on a clear, moonless evening in the country, the naked eye shows remarkable numbers of faint stars here. And telescopes show several superb open star clusters.

The clusters M46 and M47 shine at magnitudes 6.1 and 4.4, respectively, in the northwest corner of Puppis — about 15° east of Sirius. They're only 1½° from each other but appear very different. M47 consists of a few bright, scattered stars, while M46 is more orderly, with dimmer but more numerous stars. Intermediate in appearance between M46 and M47, but more compact than either, is 6.2-magnitude M93, which lies about 1½° northwest of 3.3-magnitude Xi Puppis. Southernmost (declination –39½°) but possibly best of Puppis's great clusters is 5.8-magnitude NGC 2477, which contains several hundred stars of 11th magnitude and dimmer. NGC 2477 lies just 2½° northwest of the constellation's brightest star, 2.2-magnitude Zeta Puppis, also known as Naos.

Triangles for treasure-finding in eastern Hydra. Procyon and Regulus form a nearly right triangle with Alphard (Alpha Hydrae), the lonely, orange, 2nd-magnitude heart of Hydra the Sea Serpent. The fairly dim but compact and therefore conspicuous little head of Hydra lies less than 10° due east of Procyon. Procyon and Hydra's head are the northern corners of an equilateral triangle whose other corner is marked by one of the "lost" Messier objects — the big 5.8-magnitude open cluster M48. M48, near Monoceros but just within the boundaries of Hydra, also forms a nice triangle with Hydra's head and Alphard.

There is a small triangle (roughly the size of Hydra's head) composed of rather dim naked-eye stars not too far southeast of Alphard. The easternmost star in this triangle, Mu Hydrae, lies 1¾° north of NGC 3242, the bright planetary nebula called "the Ghost of Jupiter."

East of Mu Hydrae is brighter Nu Hydrae — and they form the base of an equilateral triangle whose northerly apex is U Hydrae, one of the reddest of all stars in binoculars and small telescopes. U Hydrae varies from about magnitude 4.8 to 6.5 over a period of roughly 450 days.

The "winter home" of Halley's Comet. Halley's Comet was a 2nd-magnitude object low in the predawn sky in March 1986. Now the comet is beyond Neptune's orbit, coasting slowly toward its 2023 aphelion. Its "winter home" for the next few decades is near the celestial equator, just a few degrees south or west of Hydra's head. ✦

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

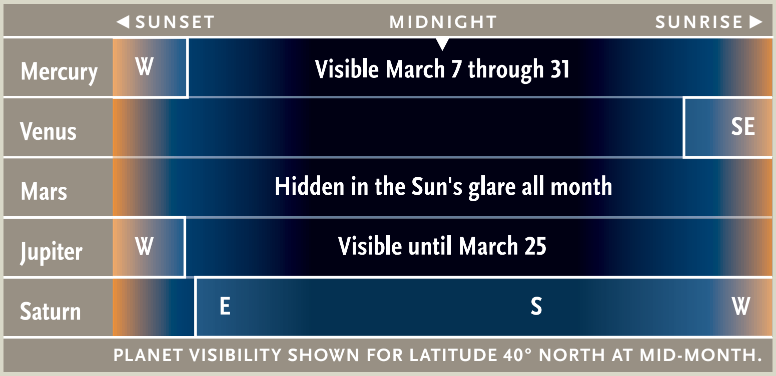
Sky at a Glance

SKY & TELESCOPE

MOON PHASES

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

PLANET VISIBILITY



STARS TRAIL ABOVE a moonlit field of canola flowers in Hungary. The volcanic hill in the background is named Csobánc.

March 2011

1 **DAWN:** Venus is to the right or upper right of the thin crescent Moon (for North America), as shown on page 49.

EVENING: Algol is at minimum brightness for roughly 2 hours centered on 9:03 p.m. PST (11:03 p.m. CST); see page 63.

4 **NEW MOON** (3:46 p.m. EST).

EVENING: Algol is at minimum brightness for roughly 2 hours centered on 8:53 p.m. EST.

5 **DUSK:** Binoculars should show Mercury lower left of a very thin crescent Moon very low in the west shortly after sunset.

6 **DUSK:** Jupiter is left of the crescent Moon.

12 **FIRST-QUARTER MOON** (6:45 p.m. EST).

13 **DAYLIGHT-SAVING TIME** begins at 2 a.m. for most of the U.S. and Canada.

13–16 **DUSK:** Mercury passes just to the right of Jupiter, as shown on page 48. This is your easiest chance to locate Mercury all year.

17–28 **DUSK:** Mercury continues its best evening apparition of 2011 for observers at mid-northern latitudes, shining more than 10° above the western horizon a half hour after sunset.

19 **FULL MOON** (2:10 p.m. EDT).

20 **SPRING BEGINS** in the Northern Hemisphere at the equinox, 7:21 p.m. EDT.

20–21 **ALL NIGHT:** Spica is near the Moon from shortly after dark until sunrise.

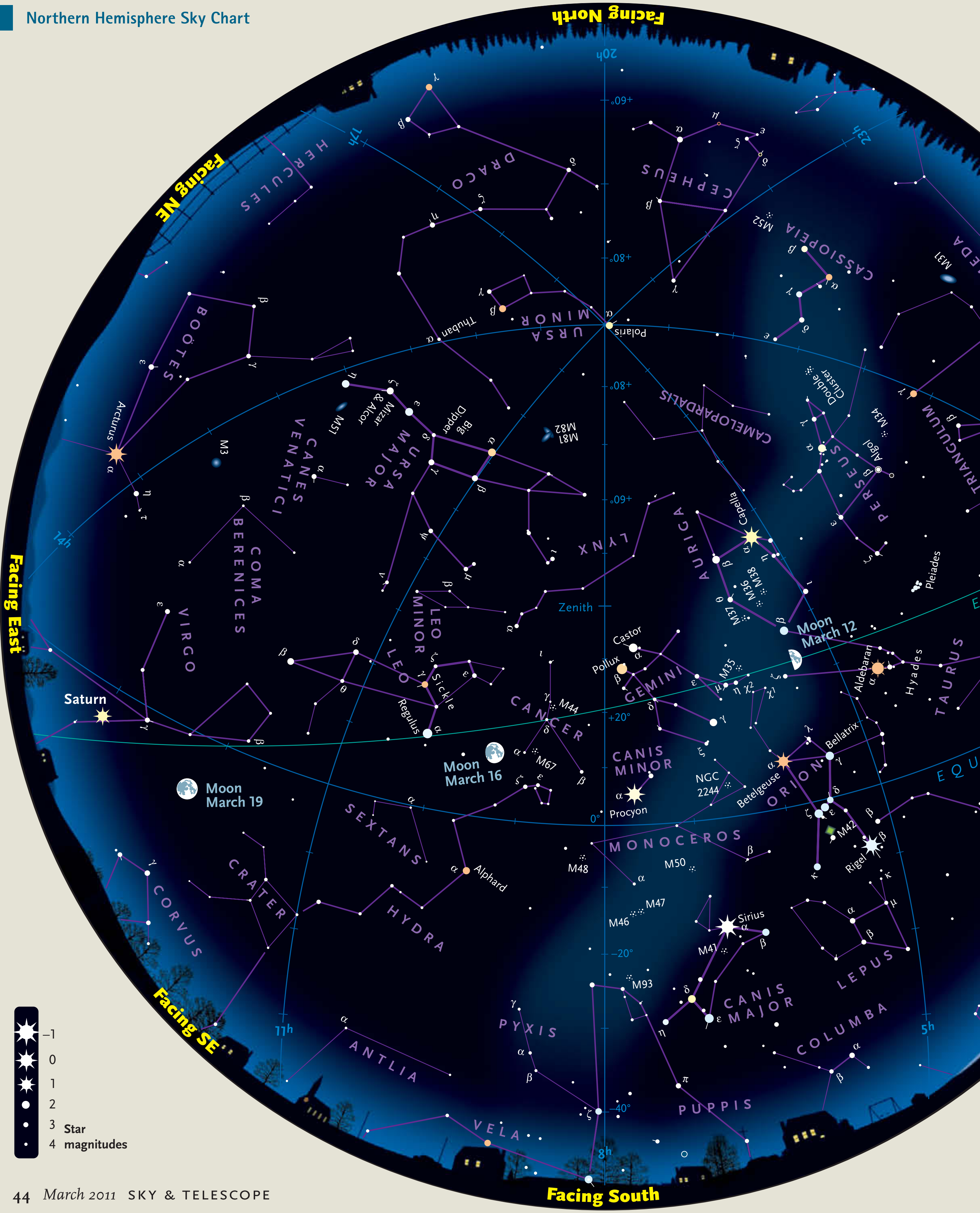
Mar. 21 – Apr. 5 **EVENING:** This is a good time to view the zodiacal light from mid-northern latitudes. Find a dark location with a clear western horizon, and start looking about 80 minutes after sunset for a vague but huge, tall pyramid of pearly light slanting upward and left along the path of the zodiac.

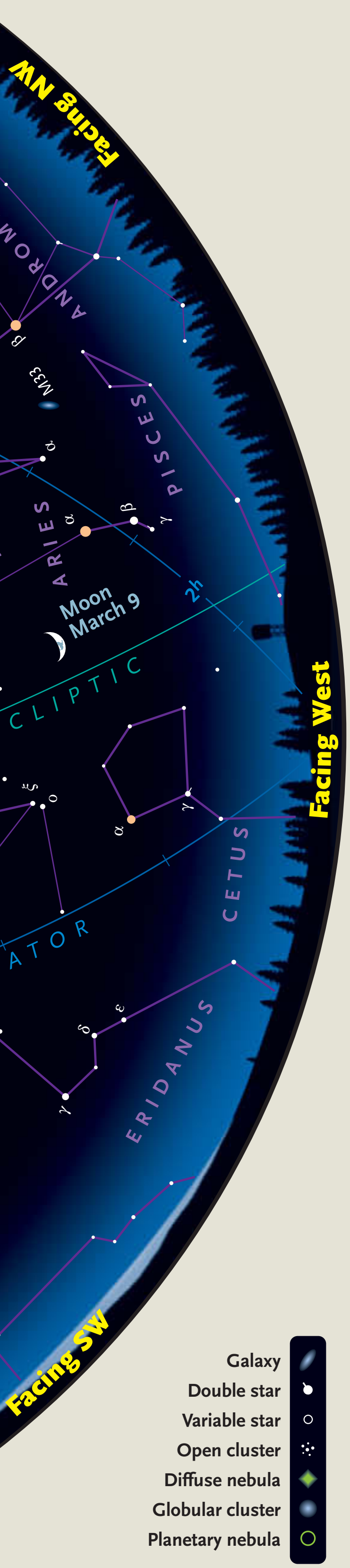
24 **EVENING:** Algol is at minimum brightness for about 2 hours centered on 8:38 p.m. PDT.

26 **LAST-QUARTER MOON** (8:07 a.m. EDT).

31 **DAWN:** Venus is lower right of the thin crescent Moon, as shown on page 49.

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


Facing North
Facing NE
Facing East
Facing SE
Facing South
20h
17h
23h
14h
11h
8h
5h
+60°
+80°
+60°
+20°
0°
–20°
–40°
Zenith
DRACO
HERCULES
CEPHEUS
CASSIOPEIA
M52
M31
BOÖTES
Arcturus
URSA MINOR
Polaris
Thuban
Big Dipper
Mizar & Alcor
M51
M3
M81
M82
URSA MAJOR
CANES VENATICI
CAMELOPARDALIS
Double Cluster
M34
Algol
PERSEUS
TRIANGULUM
COMA BERENICES
LYNX
AURIGA
Capella
M36
M38
M37
Pleiades
VIRGO
LEO MINOR
LEO
Sickle
Regulus
Saturn
CANCER
M44
M67
Moon March 16
Moon March 19
Castor
Pollux
GEMINI
M35
Moon March 12
Aldebaran
Hyades
TAURUS
CANIS MINOR
Procyon
NGC 2244
Betelgeuse
Bellatrix
ORION
M42
Rigel
EQUATOR
SEXTANS
Alphard
MONOCEROS
M48
M50
CRATER
CORVUS
HYDRA
M46
M47
Sirius
M41
LEPUS
M93
CANIS MAJOR
COLUMBA
PYXIS
ANTLIA
PUPPIS
VELA
–1
0
1
2
3
4
Star magnitudes



Using the Map

WHEN

Late January	Midnight
Early February	11 p.m.
Late February	10 p.m.
Early March	9 p.m.
Late March	Dusk

These are standard times.

HOW

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

Example: Rotate the map a little so that "Facing SW" is at the bottom. Nearly halfway from there to the map's center is the constellation Orion. Go out, face southwest, and look halfway up the sky. There's Orion!

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

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

Binocular Highlight: M93 and Company

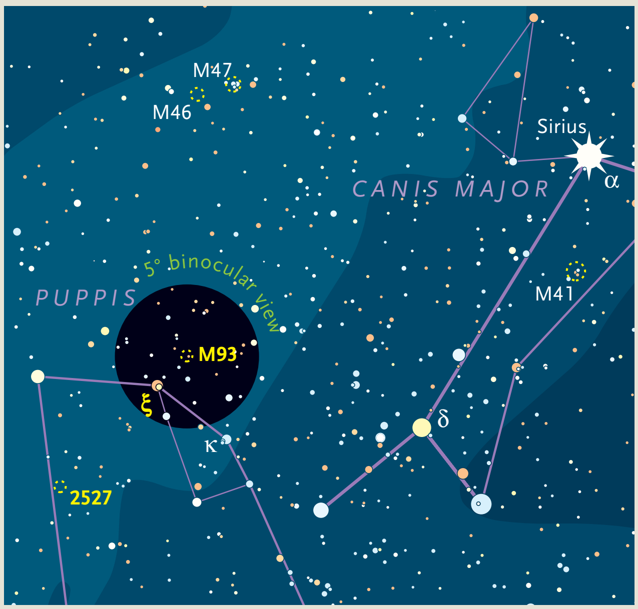
Some deep-sky objects are loners — they dominate a region of sky and reside in splendid isolation. Other binocular targets have company and share the field of view with interesting neighbors. **M93**, in Puppis, is one of the latter.

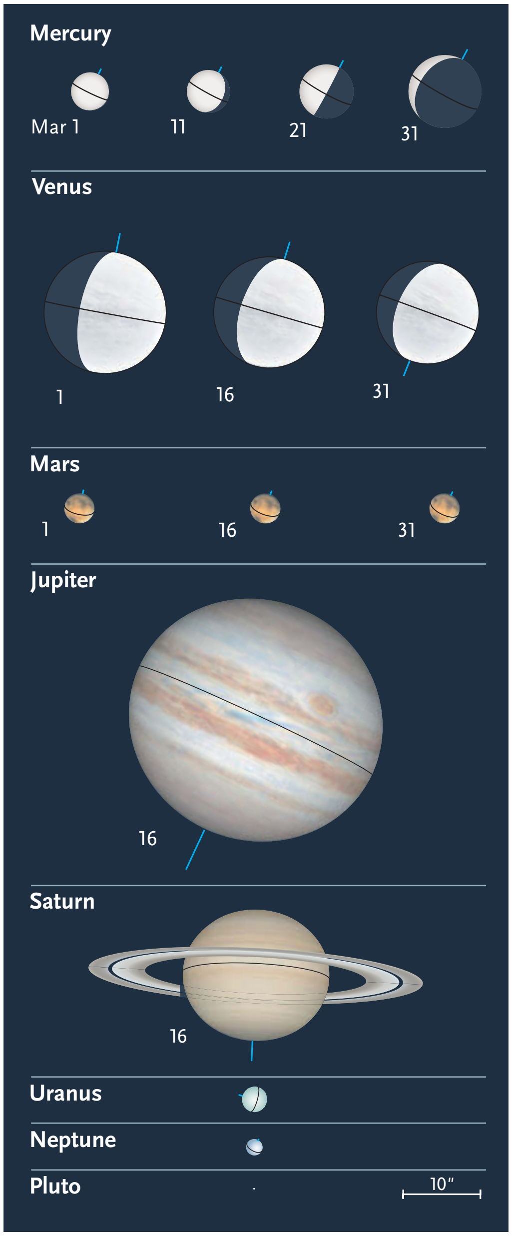
The easiest route to M93 is to begin at Delta (δ) Canis Majoris and proceed two binocular fields east to 3.3-magnitude Xi (ξ) Puppis. The 6.2-magnitude cluster is in the same field as Xi, northwest of the star. I was able to find M93 easily with my 10×30s, which show it as a rich, compact grouping crossed by a prominent east-west bar of 8th- and 9th-magnitude stars. My 10×50s provide essentially the same view, but add a little more substance to the cluster's background haze. It's a lovely grouping.

After checking out M93, return to **Xi** for a closer look. Xi is a pleasing, wide double star consisting of 3.5- and 5.3-magnitude components separated by nearly 5′. What I find interesting is that the stars appear to have different colors, even though they're both of spectral class G. This may be an illusion arising from the pairing's unequal brightness, but it's interesting nonetheless. Do you see it?

If you're up for a couple of dark-sky challenges, scan east of Xi and M93 for a short, northwest-southeast finger of dark nebulosity. This unnamed strip of darkness spans the distance between the double and the cluster and is obvious in my 15×70s. Finally, park Xi at the upper right of your binocular field and have a look to the lower left for open cluster **NGC 2527**. Listed at magnitude 6.5, this grouping shows up in 10×50s as a faint, compact patch of star mist with perhaps a dozen stars that pop in and out of view. ✦

— *Gary Seronik*



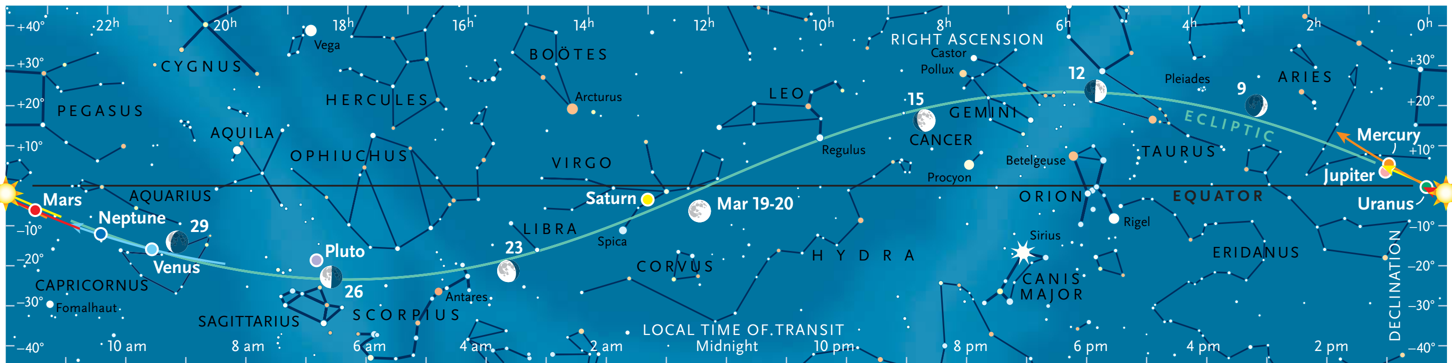


Sun and Planets, March 2011

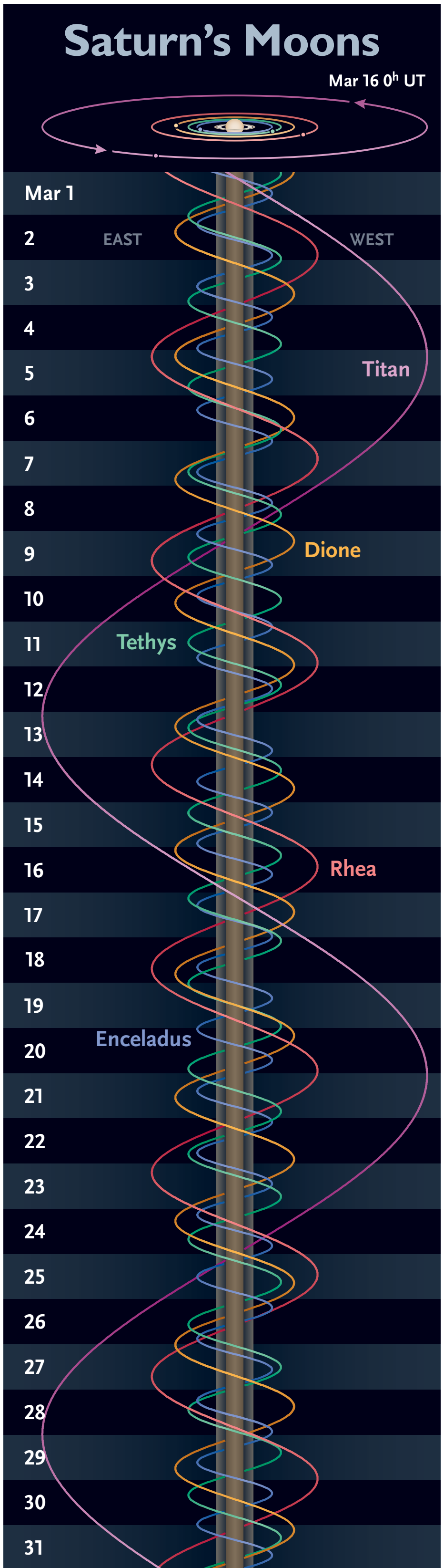
	March	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	22ʰ 45.7ᵐ	–7° 52′	—	–26.8	32′ 17″	—	0.991
	31	0ʰ 35.9ᵐ	+3° 52′	—	–26.8	32′ 02″	—	0.999
Mercury	1	23ʰ 00.0ᵐ	–8° 07′	4° Ev	–1.7	5.0″	99%	1.349
	11	0ʰ 08.3ᵐ	+0° 45′	12° Ev	–1.2	5.6″	87%	1.205
	21	1ʰ 04.0ᵐ	+8° 55′	18° Ev	–0.5	7.0″	52%	0.956
	31	1ʰ 24.7ᵐ	+12° 27′	15° Ev	+1.7	9.5″	15%	0.710
Venus	1	20ʰ 01.8ᵐ	–19° 34′	41° Mo	–4.1	15.8″	71%	1.053
	11	20ʰ 51.0ᵐ	–17° 23′	40° Mo	–4.1	14.9″	75%	1.122
	21	21ʰ 39.1ᵐ	–14° 23′	38° Mo	–4.0	14.0″	77%	1.189
	31	22ʰ 25.9ᵐ	–10° 42′	35° Mo	–3.9	13.3″	80%	1.253
Mars	1	22ʰ 27.2ᵐ	–10° 50′	5° Mo	+1.1	4.0″	100%	2.365
	16	23ʰ 11.4ᵐ	–6° 19′	9° Mo	+1.1	4.0″	100%	2.357
	31	23ʰ 54.6ᵐ	–1° 37′	12° Mo	+1.2	4.0″	99%	2.348
Jupiter	1	0ʰ 29.7ᵐ	+2° 00′	28° Ev	–2.1	34.0″	100%	5.804
	31	0ʰ 55.8ᵐ	+4° 48′	5° Ev	–2.1	33.2″	100%	5.943
Saturn	1	13ʰ 03.4ᵐ	–3° 52′	144° Mo	+0.5	18.9″	100%	8.786
	31	12ʰ 55.9ᵐ	–3° 01′	175° Mo	+0.4	19.3″	100%	8.616
Uranus	16	0ʰ 01.4ᵐ	–0° 37′	5° Ev	+5.9	3.3″	100%	21.077
Neptune	16	22ʰ 06.0ᵐ	–12° 13′	26° Mo	+8.0	2.2″	100%	30.905
Pluto	16	18ʰ 30.3ᵐ	–18° 45′	78° Mo	+14.1	0.1″	100%	32.192

The table above gives each object's right ascension and declination (equinox 2000.0) at 0ʰ 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 the 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 show the pole tilted toward Earth.



The Sun and planets are positioned for mid-March; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side). All Moon dates are in March. "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.



The wavy lines represent five of Saturn's satellites; the vertical bands are Saturn's globe and rings. Each gray or black horizontal band is one day, from 0^h (upper edge of band) to 24^h UT (GMT). The ellipses at top show the actual apparent orbits; the satellites are usually somewhat north or south of the ring extensions.

Fred Schaaf

The Changing of the Guard

Saturn shines all night after Jupiter disappears.

THE NUMBER of planets visible at dusk keeps changing in March. At the beginning of the month only Jupiter is visible, low in the west. Then Mercury begins a fine appearance there too. By mid-month it passes Jupiter, appearing higher each evening while Jupiter sinks lower.

Meanwhile, on the opposite side of the sky, Saturn has been rising earlier every night. After Jupiter and Mercury set in early evening, Saturn remains the only planet in view — until Venus rises around the start of dawn.

DUSK

Jupiter sets about 2 hours after the Sun on March 1st, when the giant planet is still the lone light low in the west during dusk.

Mercury becomes visible to the naked eye early in the second week of March, far to Jupiter's lower right, and climbs closer to Jupiter day by day. This soon becomes Mercury's best evening apparition for 2011, and Mercury's proximity to Jupiter makes it especially easy to locate. Look for it less than 5° from Jupiter on March 12th, about 3½° on March 13th, and 2½° on March 14th. On the 15th, North American viewers see the two planets at their closest — about 2° apart — and Mercury is at last slightly higher than Jupiter.

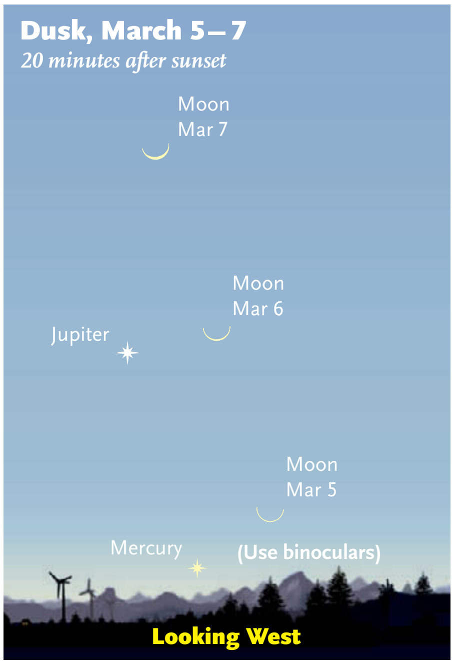
Jupiter shines at magnitude –2.1 that night (and all month), while Mercury is –1.0, about a half magnitude dimmer than when it first appeared. At the conjunction, Jupiter's fully lit disk is 33″ wide in a telescope, while Mercury's gibbous, 70%-illuminated disk is only 6.2″ wide.

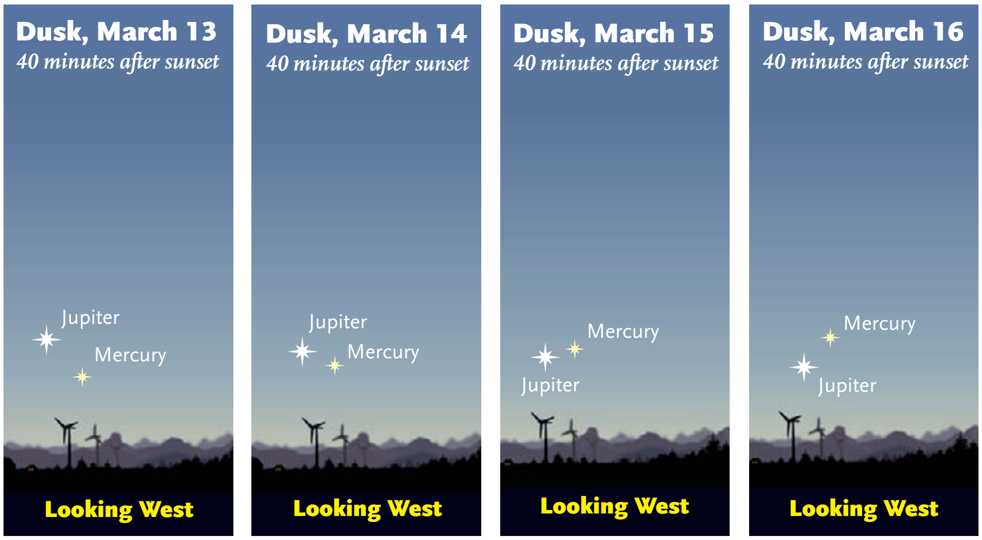
By an amazing coincidence, the two conjunction-mates are both are at perihelion (closest to the Sun in space) in the next two days: Mercury on March 16th and Jupiter on the 17th — and Mars was at perihelion on the 9th! Jupiter only reaches perihelion once every dozen years.

By late March Jupiter sets early enough to be lost in the solar afterglow. (Jupiter will reach conjunction with the Sun on April 6th.) Mercury continues to appear higher each evening after mid-month, attaining greatest elongation, 19° from the Sun, on the American evening of March 22nd. On that date Mercury shines at magnitude –0.2, and its 7.5″-wide disk is 43% lit. Even by month's end Mercury still sets an hour after the Sun — but it has faded to magnitude +1.7, making it hard to locate even with binoculars.

DUSK TO DAWN

Saturn, in Virgo, shines in the southeast during evening. It rises more than two hours after sunset on March 1st but right





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.

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

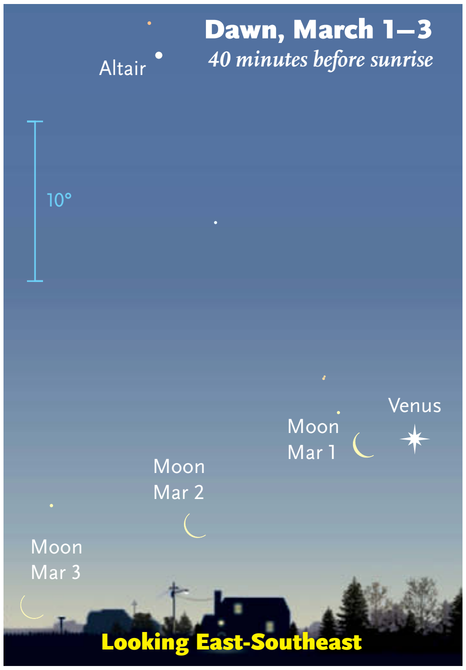
around sunset by month's end. Saturn is at opposition to the Sun on the American evening of April 3rd, just 2½ days before Jupiter reaches solar conjunction. So the two biggest planets are now essentially opposite each other in the sky, each rising when the other sets.

Saturn reaches its maximum brightness and diameter for 2011 in late March: magnitude +0.4 and 19.3″ wide. The rings are narrowing slightly, to 9° from edge-on by the end of March. Saturn is best seen through a telescope when it's highest in the sky, around the middle of the night.

By late evening observers around 40° north latitude find Saturn directly above Spica in the southeast. The planet increases its separation from Spica from 9° to 11° in March, crawling westward toward Porrima (Gamma Virginis). Saturn is 4° from Porrima by month's end. On March 13th binoculars show Saturn only 9′ from 6th-magnitude 46 Virginis.

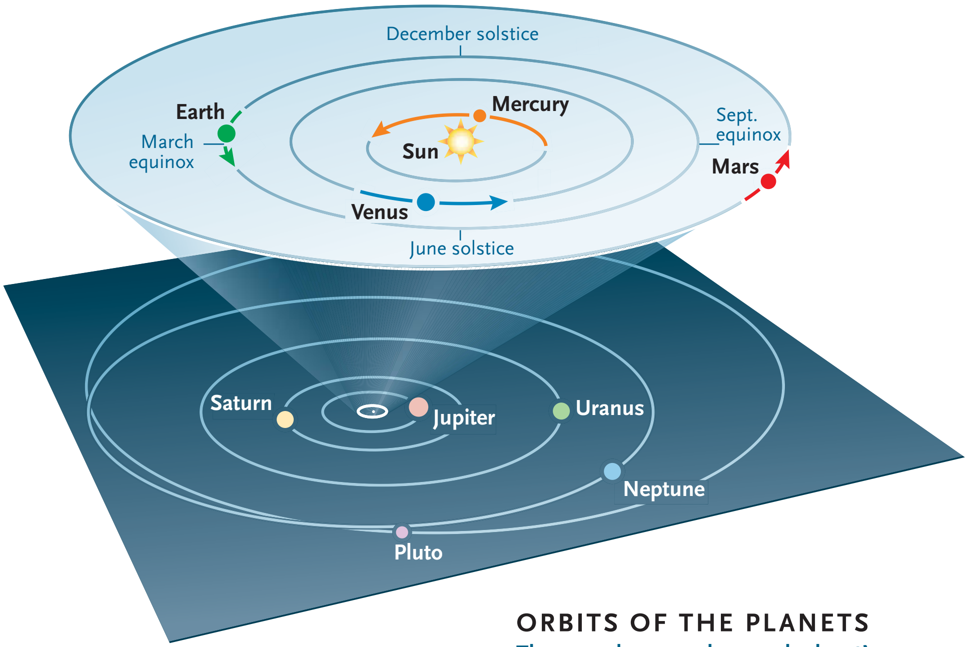
DAWN

Venus is the bright "Morning Star" low in the east-southeast during dawn. In



March its lead on the rising Sun decreases slightly, from 2 to 1¾ hours, and its magnitude dims slightly, from –4.1 to –3.9. It spends the month crossing Capricornus, passing just 9′ south of **Neptune** around 1^h UT on March 27th, when the planets are above the horizon in the predawn skies of Central Asia

By the time the two planets rise on the morning of the 27th in North America, Venus has pulled about ½° east of Neptune. A telescope will definitely show Venus's now-little gibbous disk and should show Neptune if conditions are good. But Venus outshines 8.0-magnitude Neptune by a factor of 60,000.



ORBITS OF THE PLANETS

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

Pluto glows dimly in Sagittarius at magnitude +14.1, about 250 times fainter than Neptune. It's high enough to detect in a big telescope before the sky starts to brighten, but it will be much easier to observe later in the year.

Mars and **Uranus** are lost in the glare of the Sun.

MOON AND SUN

The **Moon** stands as a thin crescent not far to Venus's left or lower left at dawn on March 1st. Just 20 minutes after sunset on March 5th, use binoculars to help look for the very thin crescent Moon low in the west with challenging Mercury to its lower left, as shown on the facing page. A somewhat thicker crescent is right of Jupiter on the evening of the 6th and above Jupiter on the 7th.

The full Moon glows well to the upper right of Saturn on the evening of March 19th and much closer upper right of Spica the next evening. At dawn on March 31st, the crescent Moon shines not far to the upper left of Venus.

The **Sun** reaches the equinox on March 20 at 7:21 p.m. EDT, starting spring in the Northern Hemisphere and autumn in the Southern Hemisphere. ✦

Thomas A. Dobbins

A Gap But Not a Void

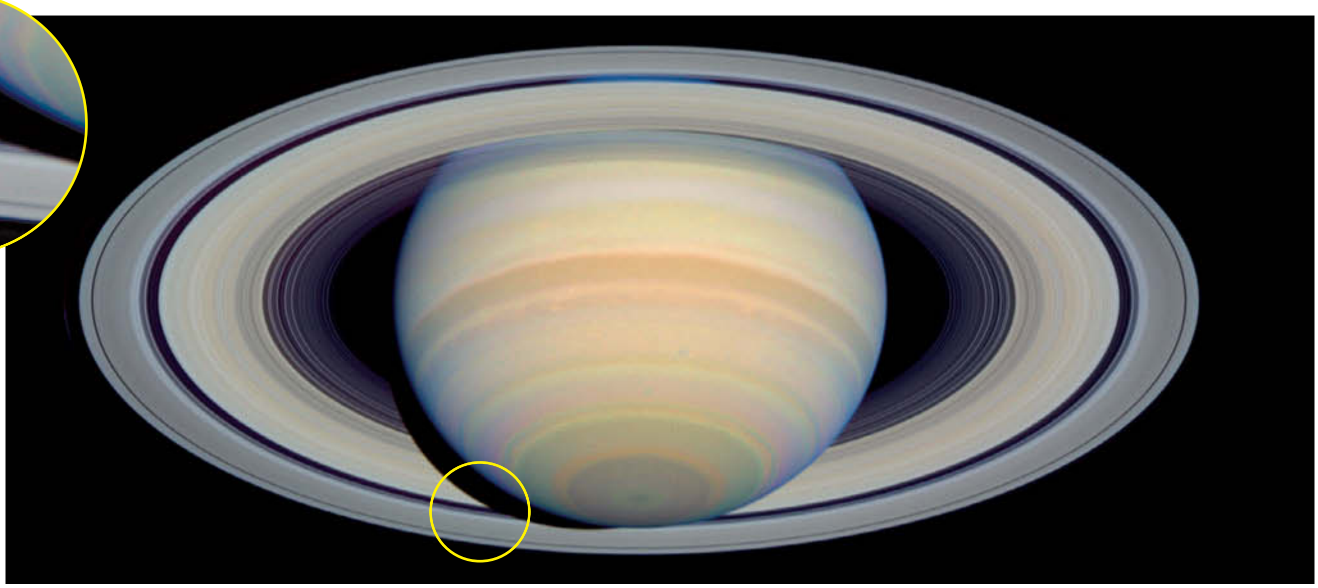
The most visible division in Saturn's rings is not devoid of material.

THE CASSINI DIVISION is by far the most prominent of the many thousands of gaps in Saturn's rings. Discovered in 1675 by Jean Dominique Cassini, it is a dark gap about 2,900 miles (4,700 kilometers) wide that separates the bright A and B rings. Although it's comparable in width to the Atlantic Ocean, the Cassini Division subtends only 0.7 arcsecond to Earth-bound observers even when Saturn is at its closest, corresponding to the apparent diameter of a penny as seen from a distance of just over 3 miles (5 km).

High-resolution images, as well as radio and stellar occultation data obtained during NASA's Voyager spacecraft flybys of the early 1980s and by the Cassini spacecraft currently orbiting Saturn, have revealed that the Cassini Division is not an empty void. The material within the gap is about five times sparser than the material in the adjacent A and B rings. Like the C ring, the Cassini Division is the site of a host of narrow concentric ringlets, some sharp-edged and opaque, others diffuse and translucent.

The Cassini Division not only bears a strong resemblance to the C ring in structure and particle density, but also in composition and color as well. The icy particles in the A and B rings reflect 40% to 50% of the sunlight that strikes them, but the particles in the Cassini Division and the C ring reflect only 15% to 20%. While the principal constituent of all of the rings is nearly pure, colorless water ice, the traces of an unknown non-icy contaminant that weakly absorbs blue light are not as prevalent in the Cassini Division or in the C ring, which lack the exceedingly subtle warm hue of the A and B rings.

If the Cassini Division is almost identical to the C ring in apparent surface brightness, why does it appear

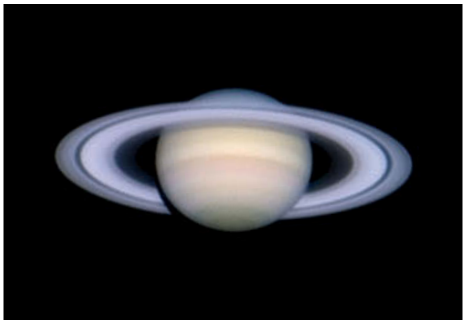


NASA / ESA / ERICH KARKOSCHKA (UNIVERSITY OF ARIZONA)

Right: **The Hubble Space Telescope recorded this view of Saturn in 2004. *Above:* The subtle difference between the jet black shadow cast by Saturn's globe on the ring system and the dusky gray Cassini Division is evident in the enhanced detail.**

NASA / JPL / SSI

Above: **This Cassini spacecraft view of the intricate structure of Saturn's rings as viewed from the unlit side reveals the uncanny similarity in particle density, color, and composition of the Cassini Division and the C ring.**



Whenever exposure times are sufficiently long to record Saturn's faint C ring, images of Saturn's rings invariably record the Cassini Division as dark gray rather than jet black. Sheldon Faworski and Don Parker captured this stunning image by using a 10-inch Takahashi Mewlon-250 and Philips ToUcam Pro on the evening of February 19, 2006. South is up.

so much darker through a telescope? After all, it isn't uncommon for visual observers to describe the appearance of the Cassini Division as "jet black" when they extol the optical performance of a telescope or the quality of the seeing during an observing session. A recently published guide to observing Saturn even advises readers that "any divergence from a completely black intensity for Cassini's Division is simply the result of poor viewing conditions, scattered light, or inadequate aperture."

The source of the illusion lies in the stark contrast between the narrow Cassini Division and the comparatively brilliant adjacent edges of the A and B rings, which are the brightest regions of the entire ring system. More than a century ago, Austrian physicist Ernst Mach demonstrated that if two unequally bright extended surfaces are brought into contact with each other, the less brilliant of the two will appear even dimmer where it appears to touch the brighter surface. On the other hand, the gap between the inner edge of the C ring and the globe of Saturn is almost devoid of matter, providing a truly black border that accentuates rather than overwhelms the faint light reflected by the C ring.

A few visual observers, some equipped with surprisingly modest instruments, have managed to overcome these difficulties. Although the Voyager spacecraft are usually credited for discovering material in the Cassini Division, the historical record clearly indicates that the spacecraft merely confirmed suspicions that had been harbored for well over a century.

The description of the tenuous matter in the C ring in the first edition of Thomas William Webb's classic observer's handbook *Celestial Objects for Common Telescopes*, published in 1859, includes a remark that "a similar material may fill Cassini's Division." Webb cited observations by the Director of the Madras Observatory in India, Captain William Stephen Jacob, who in 1852 had noted that the Cassini Division did not appear black but had the color of slate through his 6.2-inch refractor. Four years later, Jacob reported that the shadow cast by Saturn's globe across the rings "could also be seen across the dark space between the two bright rings, which therefore cannot be a mere opening but must be filled with matter of some kind."

Thomas Gwyn Elger, a keen-eyed British amateur who is remembered today chiefly for his lunar studies and map of the Moon, commented in 1888 that the Cassini Division "has never impressed me as being perfectly black" through his 8.5-inch Newtonian reflector. In 1899 the French astronomer Camille Flammarion described the appearance of the Cassini Division through his 9.6-inch refractor as "dark gray, not black" and inferred that "there is probably some matter in it." Fifteen years later his countrymen Georges and Valentin Fournier reported that on the steadiest nights, the 19.7-inch refractor of the Jarry-Desloges Observatory in Algeria showed that the Cassini Division was "not devoid of particles."

As the rings of Saturn appear to gradually open in coming years, opportunities to duplicate these challenging observations will continue to improve. Carefully comparing the appearance of the Cassini Division with the jet black shadow cast by the globe across the rings is the best way to avoid being deceived by the detrimental effects of diffraction and atmospheric turbulence. ✦

Sky & Telescope *contributing editor* ***Thomas Dobbins*** *has observed the ringed planet for well over one Saturnian year.*

Tony Flanders and Joshua Roth

Three Low-Cost Telescopes

Yes, you can buy high-quality scopes for $100 in today's market.

RAJANI FLANDERS

Authors Joshua Roth (*left*) and Tony Flanders pose with the test telescopes. The two tabletop units are attached to sturdy photo-tripod legs, their favorite setup for field use.

Orion SpaceProbe 3 Altazimuth Reflector
Orion SkyScanner 100mm TableTop Reflector
Orion GoScope 80mm TableTop Refractor

U.S. price: $99.95 (for each scope)
Orion Telescopes & Binoculars
OrionTelescopes.com;
800-447-1001

AT PUBLIC STAR PARTIES and astronomy classes, people often ask us how much they need to spend to buy a decent telescope. There are many fine options for less than $300, and at least one great telescope for less than $200 — the StarBlast 4.5-inch Astro from Orion Telescopes & Binoculars (reviewed in *S&T,* June 2003, page 46). But in the sub-$100 price range, low-quality scopes outnumber good ones by a huge margin. Up to now, our highest-rated scope in that price bracket was another unit sold by Orion: the SpaceProbe 3 Altazimuth Reflector, reviewed together with 10 other telescopes in the December 2005 issue, page 86.

So we were greatly interested when Orion introduced two new telescopes for $99.95, the same price as the SpaceProbe 3. These are the SkyScanner 100mm TableTop Reflector (a scaled-down and simplified version of the StarBlast) and the GoScope 80mm TableTop Refractor, a short-tube refractor on a nearly identical mount. Could they match or exceed the performance of the venerable SpaceProbe? To find out, late last year we purchased current versions of the three scopes and set up a shootout.

Out of the Box

Assembling the SpaceProbe for the first time might be a little daunting for some people. The instructions are very clear, and all necessary tools are included, but there are lots of individual pieces and screws. Still, anybody with normal mechanical aptitude should be able to put the scope together in a half hour or less.

The two tabletop units, by contrast, come almost fully assembled. We were observing with both scopes within five minutes of opening the boxes.

The Mounts

It's impossible to overstate how important it is for a telescope to have a steady mount that lets you point the scope smoothly and surely in all directions. Wobbly tripods and mounts that jerk or slip have long been the Achilles' heel of low-cost telescopes. Old-fashioned long-tube 60-mm refractors often had (and still have) excellent optics, but they're traditionally mated with grossly inadequate mounts that make them a misery to use, especially for beginners.

The SpaceProbe's mount looks exactly like the mounts

S&T: TONY FLANDERS

Author Flanders's daughter decided to try the SkyScanner hand-held — a surprisingly effective arrangement at 20×.

for some of those low-cost long-tube refractors, but it works vastly better. We suspect that's because the tube is in almost perfect balance. Regardless of the reason, the SpaceProbe moves smoothly and stays where you point it. It's a little wobbly, especially when the legs are fully extended, but we judge it to be well within acceptable limits as long as the air is calm. Unfortunately, it shakes a lot in a stiff breeze — hardly surprising considering that the whole setup weighs only 8 pounds.

As for the tabletop mounts, they're superb. They're shipped with the azimuth motion a little too loose, but that's easily adjusted, as explained in the owner's manual. Once that's done, their motions rival those of alt-azimuth mounts costing hundreds of dollars. The mounts work well on tables, and they also have sockets in the base allowing them to be attached to any tripod with standard $3/8$- or $1/4$-inch threaded posts.

S&T: DENNIS DI CICCO (3)

The Orion SpaceProbe 3 Altazimuth Reflector *(left)* has a time-tested yoke mount with a thumbscrew slow-motion bar (chrome) for vertical motion. The telescope is balanced well enough to work fine without the slow-motion control, but the bar makes it more stable in a breeze. The SkyScanner 100mm TableTable Reflector (*center*) is a little bigger than the GoScope 80mm TableTop Refractor (*right*), but both scopes are exceptionally compact.

The optical tubes connect to the mounts with Vixen-style dovetail bars (a de facto industry standard), making it easy to put the scopes on different mounts if desired. You can also attach the optical tubes to standard photo tripods using the ¼-20 threaded holes tapped in the dovetail bars. And the SkyScanner works surprisingly well hand-held, as shown on page 53.

The only shortcoming of the tabletop mounts is that they're not quite tall enough for the optical tubes. The SkyScanner can clear the base when pointing at the zenith, but only if it's pushed forward in the dovetail holder, making it somewhat front-heavy. And the Go-Scope's star diagonal bumps into the base even when the scope is all the way forward in its dovetail. This prevents the scope from pointing anywhere within 18° of the zenith, and risks damaging the diagonal if you push the scope too hard. (The SpaceProbe also can't point directly upward, but it can get a lot closer to the zenith.)

Optical Design

The SpaceProbe 3 is a 3-inch (76-mm) f/9.2 Newtonian reflector. (That means that its focal length — approximately equal to the length of the tube — is $76 \times 9.2 = 700$ mm.) This is a classic design that's easy to manufacture, and the relatively long focal ratio works well with inexpensive eyepieces. The manual has clear directions for collimating (aligning) the telescope's optics, a collimation tool is provided, and the mirror is center-spotted to aid the process. But f/9.2 is so forgiving of minor collimation errors that you will probably never need to adjust the mirrors.

Even when the GoScope is advanced to its foremost position in the dovetail, it can only point 72° degrees above horizontal.

The SkyScanner is a 100-mm f/4 Newtonian reflector, a much less forgiving design in terms of collimation. There's no provision for adjusting the tilt of the primary mirror. And while it's possible to adjust the secondary, there's no centering spot on the primary, making collimation a challenge. In any case, our scope arrived in good collimation right out of the box.

The GoScope is an 80-mm f/4.3 achromatic refractor. This design inevitably shows colored halos around all bright objects. But as we shall see, this scope held some pleasant surprises for us.

All three scopes have clear light paths that allow the entire light cylinder entering the objective to reach the eyepiece — at least in the center of the field of view. They're supplied with 3-element eyepieces with apparent fields of view around 50°. These work very well in the f/9.2 SpaceProbe and adequately in the other two scopes. The center of the field of view is quite crisp in all cases, but due to the short focal ratios of the SkyScanner and GoScope, stars begin to grow strange-shaped spikes about halfway to the edge of the field. Nonetheless, the overall quality is good enough to frame objects in the center of the field and locate bright stars or objects even if they just graze the edge.

Both tabletop scopes attach to their mounts with standard dovetail bars. Each bar has three detents on the side and two ¼-20 threaded holes on the bottom, the latter allowing the optical tube to be attached to a photo tripod. With the GoScope, the finder is also held with a dovetail — a great convenience.

Finders and Focusers

All three scopes use Orion's standard EZ Finder II, which projects a red dot onto a window. You view your target through the window, move the scope until the target lines up with the red dot, and you're done! It would work better at night if the red dot appeared less bright. Even so, this unit is infinitely preferable to the junky 5× finderscopes often supplied with low-cost scopes.

The SpaceProbe and SkyScanner come with standard rack-and-pinion focusers. These are perfectly acceptable at the highest magnifications we could push these scopes to,

For more information see SkyandTelescope.com/$100scopes.

but by no means exceptional. The GoScope, by contrast, uses an unconventional design where the focuser moves the front lens instead of the eyepiece — and it's truly a delight to use. The tension and gearing are just right. The focuser is smooth but not sloppy, fast yet extremely accurate.

Under the Night Sky

We tested the telescopes in an urban park, in Roth's suburban backyard, and at some fairly dark sites in Boston's outer suburbs. Targets included the Moon, Jupiter, Saturn, Venus, the Pleiades and several other star clusters, a number of galaxies, and the Orion Nebula.

Not surprisingly, the SpaceProbe 3 is the clear winner on the Moon and planets when used with its supplied eyepieces. Each scope comes with a 10-mm eyepiece, but because of the telescopes' different focal lengths this yields 35× with the GoScope, 40× with the SkyScanner, and 70× with the SpaceProbe. The SpaceProbe's extra magnification allowed us to see much more detail on the Moon and planets.

Moreover, the SpaceProbe continued to deliver the best planetary images even when we used our own eyepieces to boost all three scopes to their maximum usable magnifications. Jupiter was stunning in the SpaceProbe, showing the North Equatorial Belt in crisp detail, a hint of the South Temperate Belt, and subtle shading in the polar regions. This scope would give a 60-mm apo refractor a good run for its money.

The SkyScanner proved the weakest of the three scopes at high power. The image refused to "snap" into focus, a classic sign of spherical aberration. Nonetheless, Jupiter's North Equatorial Belt and Saturn's rings showed quite clearly even at the 40× delivered by the stock 10-mm eyepiece.

The GoScope was the surprise, come-from-behind winner. There are limits to what can be expected of an f/4.3 two-element, achromatic lens. And because it's

S&T: DENNIS DI CICCO

The GoScope's diagonal threads directly onto the optical tube. This unconventional system works well but precludes attaching accessories such as correct-image diagonals to the telescope.

impossible to suspend the laws of physics, the Moon, Venus, and Jupiter appear with garish violet haloes. But if you can ignore that, planetary images are quite good. When we used an auxiliary Barlow lens to boost the GoScope's magnification to 70×, Jupiter showed nearly as much detail as it did in the SpaceProbe. Aside from the color halo, this scope compares favorably with Orion's 80-mm f/5 ShortTube Refractor, at a fraction of the cost.

We judged the GoScope to be the overall winner for viewing star clusters. Like the SpaceProbe, it shows the stars as pinpoints, but its extra aperture makes fainter stars visible, and its low, 17.5× magnification does a much better job of framing the Pleiades than the SpaceProbe's 28×. The SkyScanner also does well in this category. Stars aren't as sharp as in the other two scopes, but SkyScanner's extra aperture makes the stars brighter, and the two effects more or less balance each other.

For galaxies and nebulae, where light-gathering capa-

S&T: DENNIS DI CICCO

Small Package, Big Impact

To an old-timer like me, it's a miracle that one can buy a well-designed, fully equipped telescope for $100. But Orion Telescopes & Binoculars doesn't stop there. The scopes reviewed here also come with a DVD boasting seven authoritative video segments on the solar system as well as a CD with a starter version of *Starry Night* — an easy-to-use "desktop planetarium" program that simulates naked-eye and telescopic views of the night sky. What's more, the disk includes a PDF of the 192-page book *Starry Night Companion* by planetarium veteran John Mosley — a comprehensive and highly readable introduction to the hobby and science of astronomy. — *Joshua Roth* bility is paramount, the telescopes perform in aperture order. The 100-mm SkyScanner is best, the 80-mm GoScope comes second, and the SpaceProbe third. The difference is particularly striking when viewing the Andromeda family: Messier 31, 32, and 110. In the outer suburbs all three scopes showed all three galaxies, but M32's appearance was barely non-stellar in the SpaceProbe, and seeing M110 required careful use of averted vision. All three galaxies were quite obvious in the SkyScanner, thanks to its additional aperture.

Conclusions

If your primary goal is great views of the Moon and planets, and you have only $100 to spend, the 3-inch SpaceProbe is clearly the scope for you. It delivers 70× right out of the box, which is enough to give gorgeous views of Saturn's rings and show quite a lot of detail on Jupiter.

The other scopes have just enough magnification to show Saturn's rings and Jupiter's main belts with the supplied eyepieces. But you would need an auxiliary high-power eyepiece or Barlow lens to get the best possible planetary views from these scopes, and that would push you well beyond the $100 limit. At that point, you have to wonder if it isn't worth spending $199.95 for the 4.5-inch StarBlast, which delivers significantly better views than any of these three scopes.

If you consider simplicity and small size a premium, the tabletop units have a clear advantage over the SpaceProbe — as long as you have some kind of table or tripod to support them. We suspect that most people will find the GoScope the more attractive of the two thanks to its fine optics and excellent focuser. But deep-sky enthusiasts may well prefer the SkyScanner because of its greater light grasp and its ability to point directly upward.

Frankly, you can't go wrong with any of these telescopes; they're all outstanding performers for their price. We just wish that scopes like these had been available when we were children! ✦

RAJANI FLANDERS

When a tabletop scope points high in the sky, it's sometimes rather awkward to look through the finder.

S&T *associate editor* ***Tony Flanders*** *owns three scopes with apertures between 60 and 100 mm, and former* S&T *senior editor* ***Joshua Roth*** *owns four.*

SHELDON FAWORSKI / SEAN WALKER

A Scope for Experts?

Novices aren't the only ones who like simple, compact telescopes. I had some free time on a clear weeknight while writing this review, so I took the GoScope and SkyScanner out for a tour of the sky in my local park. My high-quality eyepieces — similar to the ones that any experienced stargazer would likely own — bring out the best in these short-focal-length scopes. And in winter, there's an endless supply of targets for even the smallest instrument. From the Orion Nebula to the glorious Double Cluster in Perseus (pictured here), I've rarely had such an enjoyable couple of hours.

— Tony Flanders

Whither ATMing?

Are amateur telescope makers becoming an endangered species?

In September 1998, soon after I settled into my desk at *S&T*, Roger Sinnott presented me with a huge mail tub filled with ATM article submissions. Since I was taking over the telescope-making department from Roger, that tub had become my weighty responsibility. Those were my halcyon days of overseeing the department, with far more material submitted than we could ever fit in the magazine. Fast forward to the present, and I'm fortunate to receive a single unsolicited article in a month. Is this a sign that telescope making is becoming a thing of the past? To get a broader perspective, I sought out the opinions of several prominent ATMs.

Telescope making, like other aspects of amateur astronomy, has had its ups and downs. But as Oregon ATMer Mel Bartels notes, "There are probably more telescope makers today than in 1965 when I started out. Of course, there are more people now too, so I reckon that the percent of the population participating in ATMing has remained roughly constant over the past 45 years."

Don Surles presides over the annual Mid-Atlantic Mirror Making Seminar, held each March in Delaware. Working with new ATMs leaves Don feeling optimistic. "I've been pleasantly surprised for the past 10 years at how fast our event fills up," he remarks. "My guess is that amateur mirror making is not only alive, but in very good condition. I also believe that, thanks to new tools and techniques, amateur-made mirrors are better today than at any time in the past."

Don makes a good point — with computerized mirror-test analysis and powerful design software, the hobby has seen the emergence of better optics, as well as new kinds of instruments. One example is Ed Jones's Chiefspiegler telescope, which was featured in our November 2008 issue, page 87. "I guess I was a little disappointed that more interest wasn't generated by the Chiefspiegler," says Ed. "I think it reflects back on the fact that there may be fewer telescope makers today."

Ed's pessimistic reading of the situation might be falling prey to the ATM community's tendency to approach new concepts cautiously. Initially the Dobsonian design was greeted with skepticism, especially by entrenched telescope makers. It was a new generation of hobbyists that pushed the Dobsonian into the mainstream.

So what are we to conclude from these disparate opinions? I suspect that there are fewer builders today, but that doesn't mean that telescope making is in trouble. Historically, amateurs have been reluctant builders. It was often the expense of commercial telescopes that drove them to build their own. Many wouldn't have become ATMs if they could have afforded to buy.

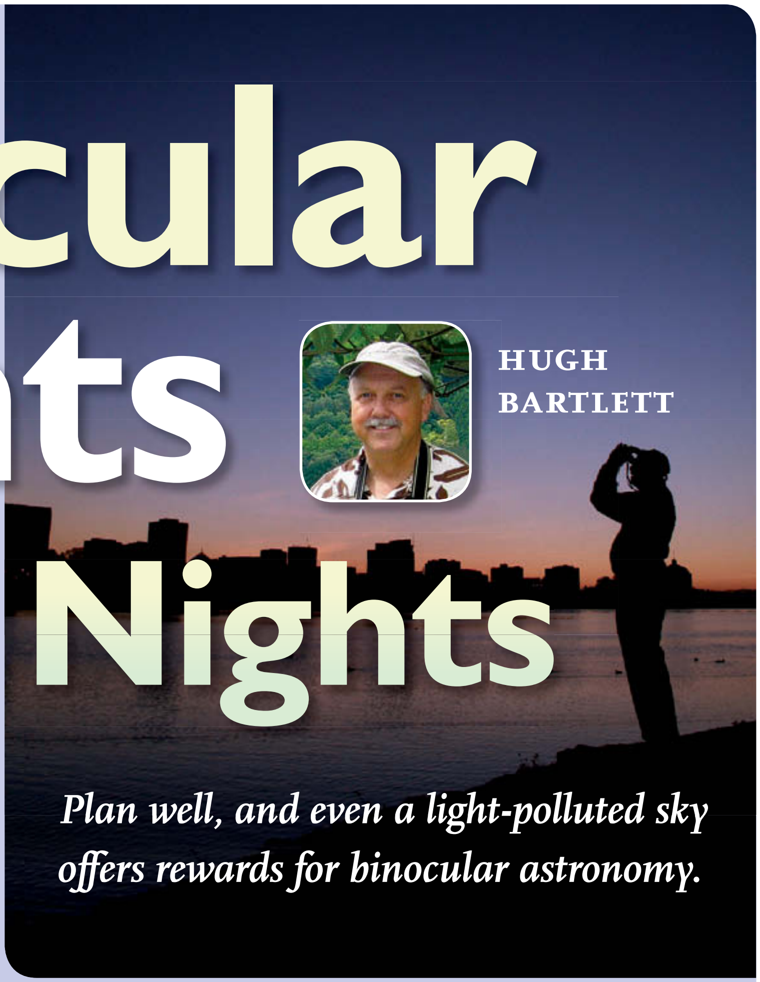
With so many inexpensive scopes available today (see page 86), fewer people are turning to ATMing. Gone are the "reluctant" builders of the past — those who remain are the hobby's vital core of individuals driven by the desire to craft something with their own hands purely for the joy of it. Such ATMs have always been in the minority, but they exist and they keep moving the hobby forward. ✦

Gary Seronik *can be reached at www.garyseronik.com.*

The annual Mid-Atlantic Mirror Making Seminar, organized by Don Surles (seen here grinding a 10-inch mirror) and hosted by the Delmarva Star Gazers of Delaware, fills up quickly.

DON SURLES

Binocular Sights for City Nights



HUGH BARTLETT

Plan well, and even a light-polluted sky offers rewards for binocular astronomy.

CATHY COOKE EVERS

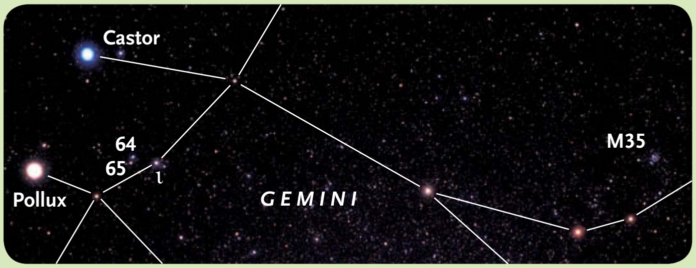
Good observing is about good planning — whether you're a professional who's waited years for a precious 50 minutes on the Hubble, or a hobbyist with a star atlas and binoculars just taking an after-dinner step outdoors away from Earthly concerns.

"Planning" means knowing what your instrument will and will not do, and charting out projects accordingly.

Here's the third in my series on binocular showpieces, both famous and unfamiliar, for observers under light-polluted skies who may not realize what's available even under poor conditions.

The photos here serve as finder charts for many of the sights, but every amateur astronomer needs at least one detailed star atlas. For binocular observing, I like the *Pocket Sky Atlas*. It's compact, inexpensive, and it shows all stars to magnitude 7.6, with hundreds of deep-sky objects to magnitude 10, 11, or 12 depending on type. The descriptions here give each object's right ascension, declination, and *Pocket Sky Atlas (PSA)* chart number.

***Hugh Bartlett** shares the sky with the public at the Chabot Space and Science Center in Oakland, California. You can e-mail him at hughandmaret@earthlink.net.*



ASTROPHOTOS BY AKIRA FUJII

64, 65 Geminorum — **Star pair**
RA: 7^h 30^m — **Dec: +27.9°**

A little-noticed binocular gem in the field of Castor and Pollux is this naked-eye doublet, magnitudes 5.0 and 5.1, separation ¼°. Close examination with binoculars reveals muted tones of yellow and white. Just to the west (right) are brighter Iota (ι) Gem and its wide companion 59 Gem — also yellow and white, magnitudes 3.8 and 5.8. *PSA Chart 25.*

M35 — **Open Cluster**
RA: 6^h 09^m — **Dec: +24.4°**

This faint smudge above Castor's trailing foot is a huge (½°) city of more than 200 stars about 2,800 light years away, producing enough photons to show through all but the brightest urban skyglow. *PSA Chart 25.*

M44 — **Cluster in Cancer**

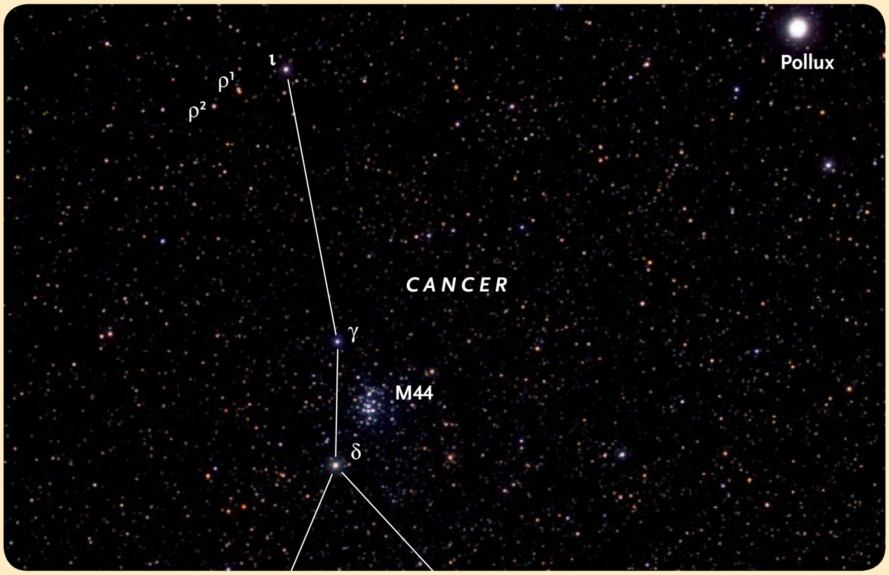
RA: $8^h\ 40^m$ — **Dec: +19.7°**

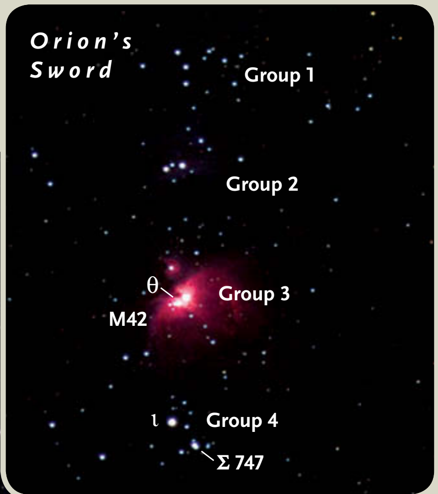
The brightest members of the Beehive Cluster form a dome-shaped beehive with bees buzzing out of its top and swarming around. It contains multiple star groupings; the most striking is the yellow-and-white pair forming the beehive's peak on the north: 39 and 40 Cancri, magnitudes 6.5 and 6.6, separation 150″. *PSA Chart 24.*

Rho^1 (ρ^1) Cancri — **Double star**

RA: $8^h\ 53^m$ — **Dec: +28.3°**

From M44, sweep 9° north to pick up Iota Cancri (a pretty telescopic double). Slightly more than 1° east-southeast from Iota are Rho^1 (55) and 53 Cancri, a pair of yellow and orange-yellow beacons, magnitudes 6.0 and 6.3, separation 278″. Rho^1 is known to have five planets, including one of the first discovered outside the solar system. A little farther on in the same direction is Rho^2, a single star. *PSA Chart 24.*

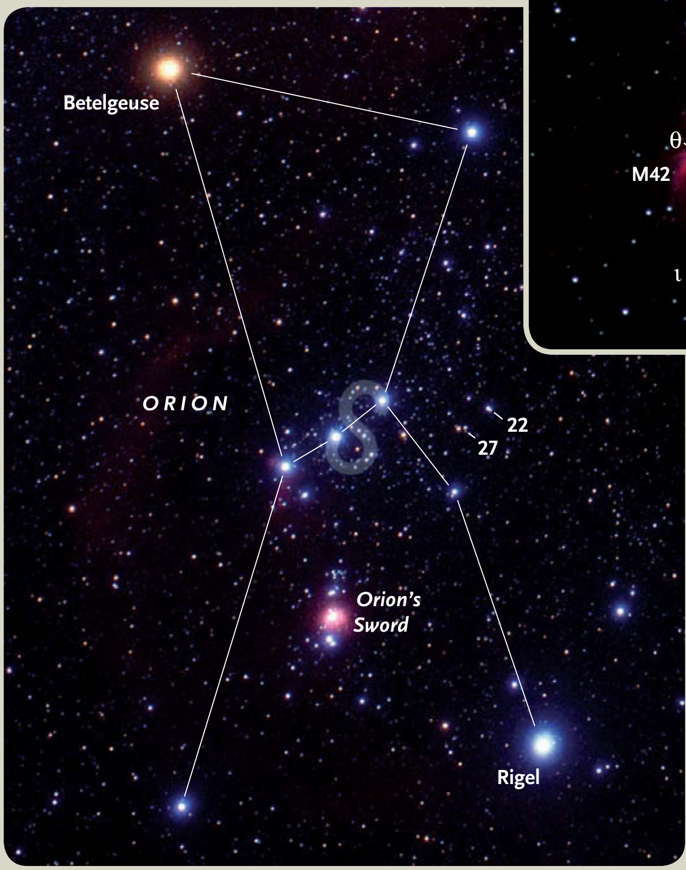




Orion's Sword — **Asterism**

RA: $5^h\ 35^m$ — **Dec: –6°**

No matter how often you return here, you can always learn Orion's Sword in a little more depth. Its basic structure is four multiple-star groups in a north-south row. Group 1 is the loose open cluster NGC 1981. Group 2 includes 42 and 45 Orionis. Group 3 sports the Great Orion Nebula, M42, with the binocular double Theta (θ) Orionis at its heart. Can you see other stars in the nebula? Group 4 is highlighted by Iota (ι) Orionis, magnitude 2.8. Just 8′ southwest of Iota is the lovely but tight binocular double Struve 747 (Σ747), magnitudes 4.8 and 5.7, separation 36″. *PSA Charts 16 and Closeup B.*



Orion's Belt — **Asterism**

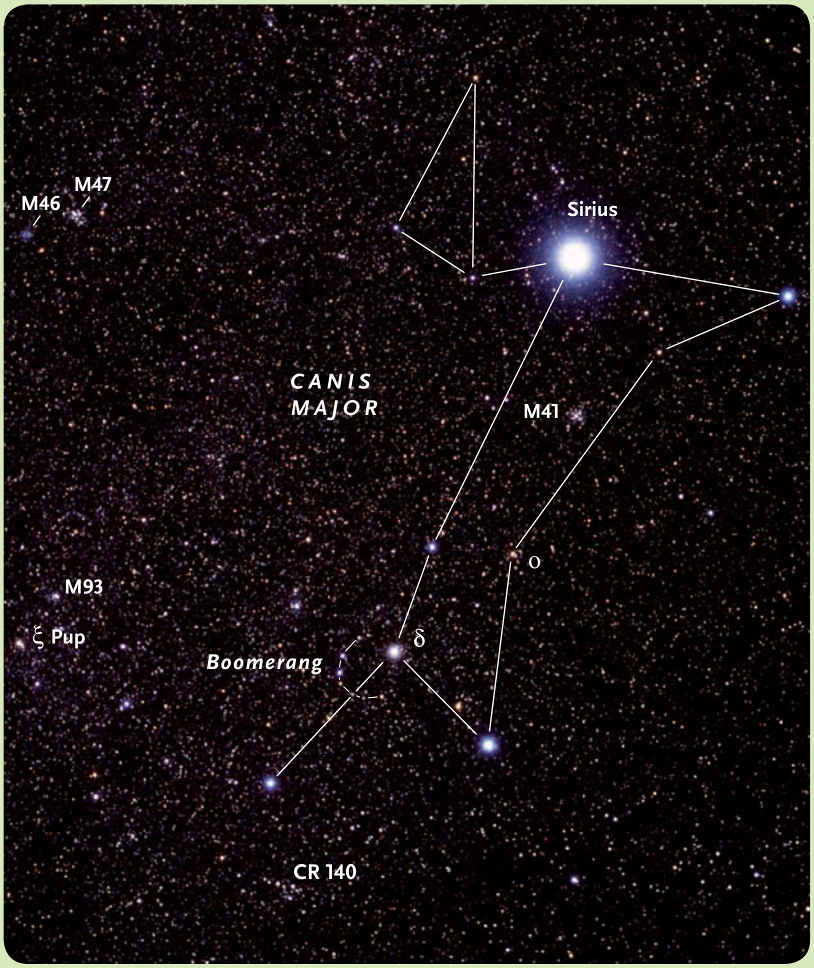
RA: $5^h\ 35^m$ — **Dec: –1°**

There's more in Orion's Belt too than many observers notice. Trace out "Orion's S," and note the red giant inside the S's bottom loop. How much of the Orion's Belt field do you know well enough to draw from memory? *PSA Chart 16.*

22 and 27 Orionis — **Two star pairs**

RA: $5^h\ 20^m$ — **Dec: –1°**

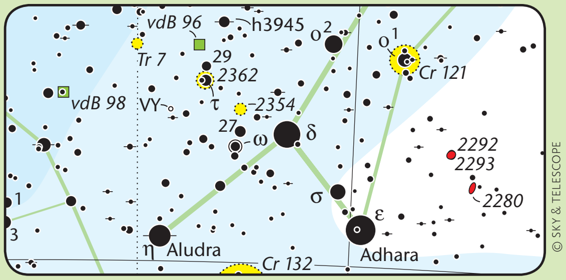
Just west of Orion's Belt are two easy binocular doubles that few skywatchers know. The slightly brighter one is 22 Orionis and its companion: magnitudes 4.7 and 5.7, separation 242″, both blue-white. One degree southeast are yellow-orange 27 Orionis and its white companion: magnitudes 5.1 and 6.1, and more than twice as wide at 571″. *PSA Chart 16.*



Boomerang — **Asterism in Canis Major**

RA: 7^h 15^m — **Dec: –26°**

This 2° semicircle of 4th- to 6th-magnitude stars is centered on Delta Canis Majoris, the Big Dog's rump. You can extend the Boomerang's north end farther northwest and west (right) with fainter stars to more than double its size. David Elosser of Kernersville, NC, sees a goose here. What do you make of this group? E-mail me at the address on page 58. *PSA Chart 27.*



Sirius — **Brightest star**

RA: 6^h 46^m — **Dec: –16.7°**

Sirius is not only the brightest star in the night sky but, at a distance of 8.6 light-years, it's the *closest* nighttime star visible to the naked eye from mid-northern latitudes. (A few faint red dwarfs are closer). When seen in binoculars low through thick air, Sirius often flashes in vivid, prismatic colors. At higher altitudes on many nights it practically buzzes with faster, icy shimmers. *PSA Chart 27.*

M41 — **Open cluster below Sirius**

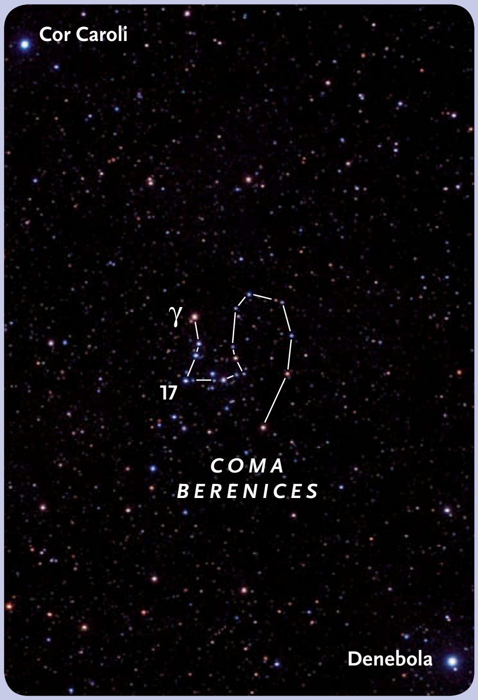
RA: 6^h 46^m — **Dec: –20.8°**

Look one binocular field south of Sirius for this coarse group centered around two amber giant stars. Just to its south-southeast is slightly brighter 12 Canis Majoris. Note the landmark triangle of 5th- and 6th-magnitude stars 2° to the cluster's east (left). *PSA Chart 27.*

Xi (ξ) Puppis — **Double star**

RA: 7^h 49^m — **Dec: –24.9°**

From the star at the end of Canis Major's tail, shift northeast 7° (a little more than one binocular field) to find this yellow supergiant with a yellow giant companion. They're magnitudes 3.3 and 5.3, separation 300″, and are not physically related. See also page 45. *PSA Chart 26.*



Coma Star Cluster — **Open cluster**

RA: 12^h 25^m — **Dec: +26°**

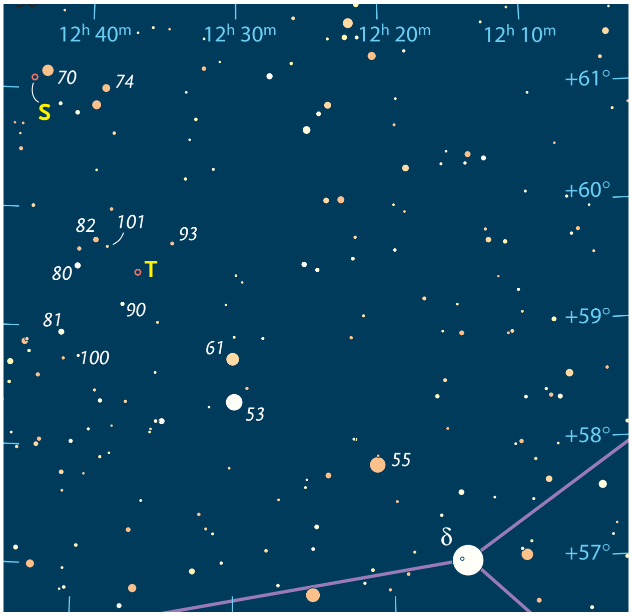
Best seen in wide-field binoculars, this 5°-wide cluster lies halfway between Cor Caroli (α Canum Venaticorum) and Denebola (β Leonis). Its bright stars form the cryptic glyph outlined above. Forming one corner of the glyph is the binocular double 17 Comae, magnitudes 5.2 and 6.6, separation 146″. *PSA Chart 45.*

A Mira by the Dipper

Keep track of this pulsing red giant with binoculars or a small telescope.

THE BIG DIPPER climbs the northeastern sky on February and March evenings, and very close to it is a deeper, more changeable sight to keep watch on. T Ursae Majoris, a red Mira-type variable star, pulses from about magnitude 13.0 to 7.7 and back every eight months. It should reach maximum brightness around February 22nd, fade slowly for several weeks afterward, and then drop more rapidly.

To find it, start from the star where the Dipper's handle joins the bowl (Delta Ursae Majoris) as shown on the diagram below. The little blue rectangle there shows the area covered by the larger chart.

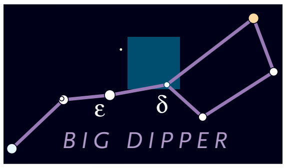


Using your finderscope, shift 2½° northeast from Delta to pick up a north-south pair of 5th- and 6th-magnitude stars ⅓° apart. From there, hop 1° northeast to T and its surroundings. The numbers next to stars are their visual magnitudes to the nearest tenth with the decimal point omitted. Notice in particular the two stars about 8th magnitude ½° to T's east, forming a triangle with it.

To use the map, you'll need to orient it to your telescope's view. On all our star maps, celestial north is up and east is left. To find where north is in your view, nudge your scope slightly toward Polaris; new stars will enter from the north edge. Turn the map around to match.

East is 90° counterclockwise from north if your telescope gives a *correct-reading* image, as a Newtonian reflector does. If your scope has a right-angle star diagonal, it probably gives a *mirror image* instead. In that case east is clockwise from north, and you'll have to mentally flip the map left-for-right.

The variability of T Ursae Majoris was discovered in 1860 by the astronomers at Bonn Observatory in Germany who were compiling the great *Bonner Durchmusterung* star catalog and atlas. The star's peaks have sometimes been as bright as magnitude 6.6 and as faint as 9.

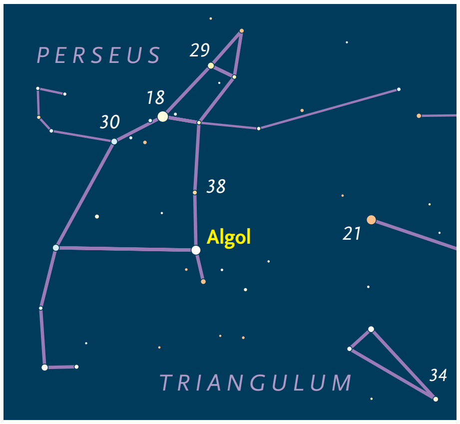


Twilight Lunar Occultation

The third-brightest star that the Moon will occult this year for North America slides behind the Moon's dark edge after sunset on **Sunday, March 13th,** for observers in the Northeast and along the Eastern Seaboard. The star is Mu (μ) Geminorum, magnitude 3.2 and orange-red. The Moon will be just past first quarter and very high in the south.

Some disappearance times: Halifax, 9:28 p.m. ADT; Montreal and central Massachusetts, 8:06 p.m. EDT; Toronto, 7:51 p.m. EDT; Washington, DC, 7:53 p.m. EDT; Miami, 6:59 p.m EDT. In most of this range the occultation happens in twilight, sometimes bright twilight. Farther west it happens in daylight. Be sure to set up early — which will be easy with the Moon so bright and well placed.

For a larger timetable and a map, go to www.lunar-occultations.com/iota/iotandx.htm and scroll down to "Upcoming Occultation Events." Here you'll also find listings of all the brightest occultations worldwide for the year.



Algol, now high in the northwest, usually shines at magnitude 2.1 but fades to 3.4 every 2.87 days. It remains near minimum light for two hours and takes several additional hours to fade and to rebrighten. The numbers here are comparison star magnitudes with the decimal points omitted.

Minima of Algol

Feb.	UT	Mar.	UT
1	12:50	2	5:03
4	9:39	5	1:53
7	6:28	7	22:42
10	3:18	10	19:32
13	0:07	13	16:21
15	20:57	16	13:10
18	17:46	19	10:00
21	14:35	22	6:49
24	11:25	25	3:38
27	8:14	28	0:27
		30	21:17

These geocentric predictions are from the heliocentric elements Min. = JD 2452253.559 + 2.867362*E*, where *E* is any integer. Derived by Gerry Samolyk (AAVSO), they reflect a slight lengthening in the star's period that seems to have occurred in early 2000.

Asteroid Occultations

Two nice asteroid occultations are predicted for North America in March:

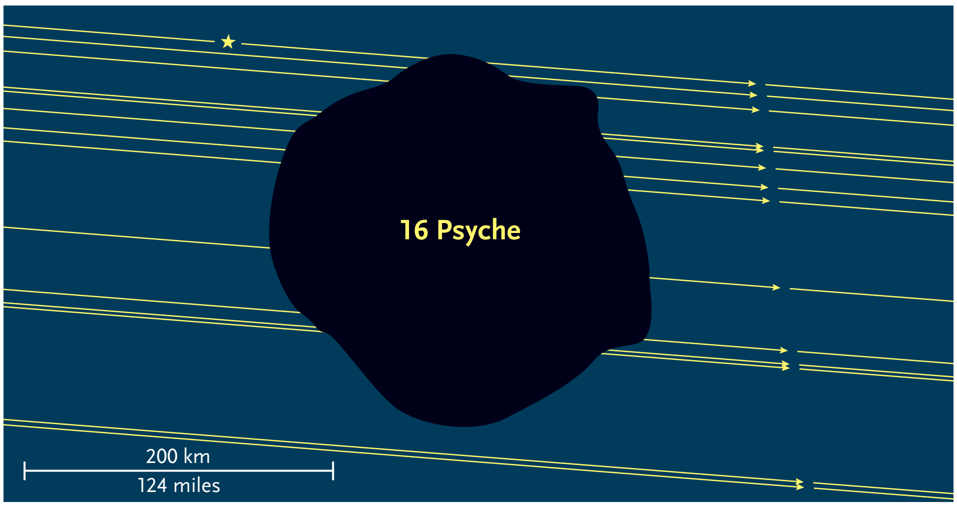
Late on the night of **March 8–9,** 12th-magnitude 72 Feronia hides the 8.4-magnitude star SAO 138141 in Leo as seen from a narrow track from Haiti across the Florida Keys and Louisiana to Oregon. The star may be gone for up to 7 seconds.

On the morning of **March 20th,** 12th-magnitude 224 Oceana occults the 8.3-magnitude star SAO 138776 in Virgo for up to 5 seconds as seen from a track running from Lake Superior to southern Alaska.

For many more asteroid-occultation predictions worldwide all year, see www.asteroidoccultation.com/IndexAll.htm.

For lots more about observing and timing these events: www.asteroidoccultation.com/asteroid_help.htm. ✦

Last August, 12 observers at different locations accurately timed the asteroid Psyche occulting a star (yellow lines), yielding an outline of Psyche's size and shape.



Oddities in Northern Orion

Look beyond the constellation's well-known showpieces.

Many a night from yonder ivied casement, ere I went to rest,
Did I look on great Orion sloping slowly to the West.
— Alfred, Lord Tennyson, *Locksley Hall*

ORION DRAWS our gaze with its splendid panoply of stars and alluring deep-sky wonders. Yet many intriguing marvels go unnoticed, lost among the constellation's glorious riches. Let's explore a few of these little-known treasures, starting near Orion's belt and wending our way northward.

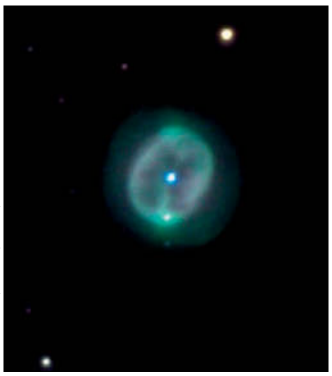
We'll begin with the little star group **FSR 983**. In 2007 astrophysicists Dirk Froebrich, Alexander Scholz, and Claire Raftery listed it as a possible cluster based on star-density maps derived from the Two Micron All Sky Survey. However, current catalogs indicate that the stars are not moving together through space. The asterism was brought to my attention by French amateur Alexandre Renou, who independently discovered it the following year.

FSR 983 is located halfway between 22 and 25 Orionis, which share a finderscope's field of view, and it's bracketed by a nearly east-west set of 8.8-magnitude stars 11′ apart. At 23× with my 130-mm (5.1-inch) refractor, the group merely looks like a small hazy area with 4 stars, but 102× reveals a nice little gathering of a dozen stars cozied together in 4½′ × 2½′.

Next we'll visit the perfectly matched double star **52 Orionis,** which shares a finder field with Betelgeuse in Orion's shoulder. Each pale yellow-white component shines at magnitude 6.0. They're aligned northeast-southwest and only 1.1″ apart. Although it's easier to split equal pairs than unequal ones, this is a challenging test for small telescopes. With the exceptional seeing (atmospheric steadiness) prevalent at the Winter Star Party, I've separated the twins with my 105-mm refractor at 203× and my 130-mm at 234×. Even at those magnifications, they looked very snug. Do you have seeing good enough to part this pair?

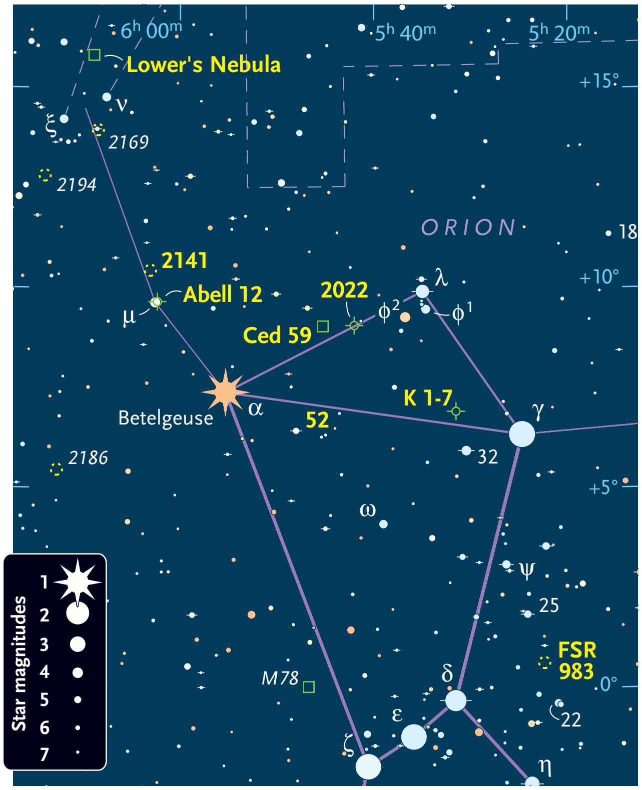
In an e-mail last year, British amateur Sakib Rasool suggested writing about young stellar objects with cometary reflection nebulae. One such object is the star/disk combination known as FU Orionis and its associated nebula **Cederblad 59**. The star is in the early stages of its evolution, still girdled by a disk of gas and dust. Near the close of 1936, inflow of material from the disk must have increased dramatically. The inner disk greatly brightened, far outshining the star, and swelled the amount of matter being dumped onto the nascent star. Disk and star brightened from 16th to 9th magnitude over the course of a few months. FU Ori has hardly faded since then, but it varies irregularly between about magnitude 9.3 and 9.8 on a timescale of weeks or days.

POSS-II / CALTECH / PALOMAR OBSERVATORY



ADAM BLOCK / NOAO / AURA / NSF

***Far Left:* The cometary nebula Cederblad 59 is embedded in the inconspicuous dark nebula Barnard 35. A subtle band of light lines B35's western edge. *Left:* The bright spot at the southwestern end of NGC 2022 is a faint star superposed on a concentration in the planetary nebula's outer ring. North is to the upper right.**



FU Orionis and Cederblad 59 sit 2.1° east of deep yellow Phi² (φ²) Orionis. In my 105-mm refractor, they simply look like a fuzzy star embedded in the inconspicuous dark nebula Barnard 35. The view is much improved with my 10-inch reflector at 70×. B35 is a nearly starless region about 25′ long and one-third as wide, elongated west-northwest to east-southeast. Near its heart, small faint Ced 59 enfolds FU Ori and broadly fans northeastward.

Bipolar outflows from FU Ori sculpt two bowl-shaped hollows in B35. The light from the yellowish inner disk and its star is scattered by the remaining dust and the walls of these hollows. We see one of them as comet-shaped Ced 59, but the corresponding nebula on the far side of the disk is heavily obscured. On images of the area, a semicircular arc of nebulosity starts 7′ south of FU Ori, runs around the western side of B35, and ends 19′ north of the star. I didn't see this thin ribbon of light. Can you?

Just 48′ west of FU Ori, **NGC 2022** is the brightest planetary nebula in Orion. My 105-mm refractor at 87× shows a small, round, blue-gray disk, while 275× suggests a slightly darker center and brighter patches on the nebula's northeast and southwest edges. My 10-inch scope at 220× confirms the view and makes it clear that the nebula is an oval tilted north-northeast.

The part of NGC 2022 visible through my telescopes is about 21″ × 18″, but it has an outer halo ½′ across. Folks with 18-inch telescopes have been able to see traces of this halo as well as a sparkle that may be the dim star superposed on the southwestern rim of the bright annulus.

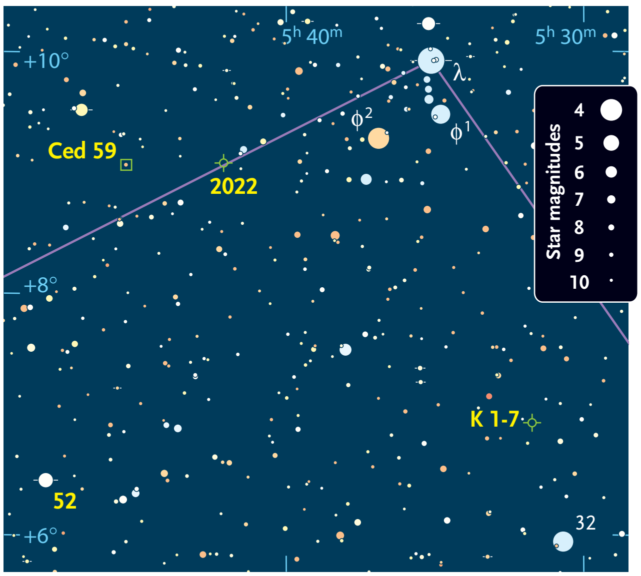
Pinned to Orion's western shoulder, the planetary nebula **Kohoutek 1-7** was discovered in 1962 by Czech astronomer Lubos Kohoutek while examining *Palomar Sky Atlas* prints. It sits 1° north of 32 Orionis in the slanted (western) side of a 5′ trapezium of stars, magnitude 10½ to 12½. K 1-7 is visible in my 130-mm scope at 102× as a small, faint, round glow with a very faint star close to its south-southeastern edge. Averted vision helps the nebula stand out better, as does boosting the magnification to 164×. A nebula filter makes the view too dark, but an O III filter offers significant improvement when I use my 10-inch reflector.

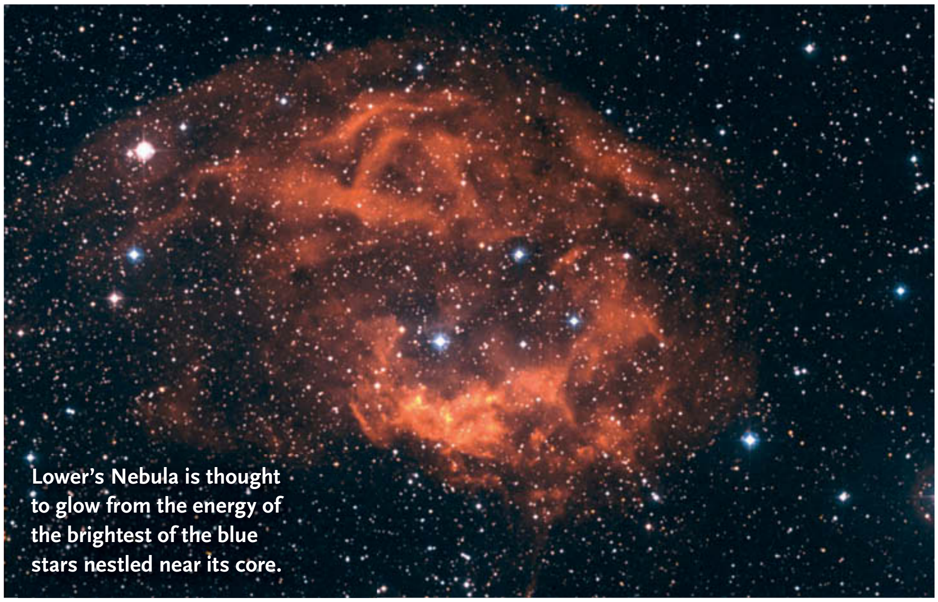
K 1-7, also known as Abell 10, is a relatively easy catch for folks who enjoy collecting Abell planetaries — yet Orion contains an even brighter one. There's a good chance that **Abell 12** would have made it into the *New General Catalogue* (NGC) if it weren't hiding in the glare of Mu (μ) Orionis, just 50″ to its east-southeast.

To view Abell 12, I affix a thin strip of aluminum foil to the field stop of my eyepiece with rubber cement. A strip of electrical tape works fine, too. When Mu is hidden behind this occulting bar, Abell 12 is very easy to see as a moderate-size, roundish planetary with my 10-inch reflector and an O III filter at 147×. This same trick lets me glimpse the nebula through my 130-mm refractor at 111×.

Climbing 49′ north of Mu brings us to the ancient open cluster **NGC 2141**. A 2009 journal paper deduces an age of 2.2 to 2.4 billion years. Only very rich clusters can hold their stars together for such a long time, but since the cluster is 13,000 light-years away, its many stars appear quite faint through a backyard telescope.

Through my 130-mm scope at 63×, NGC 2141 is an 8′ granular patch adorned with a dozen very faint stars and framed by a wheel of brighter ones. At 102× the cluster has a delicate charm, with many stars popping in and out





Lower's Nebula is thought to glow from the energy of the brightest of the blue stars nestled near its core.

POSS-II / CALTECH / PALOMAR OBSERVATORY

of view as I shift my gaze. Quite a few of these may be foreground stars, because the cluster's brightest possible members are 12th magnitude.

Our final target is **Lower's Nebula** (Sh 2-261), discovered on a photograph taken with the 8-inch f/1 Schmidt camera built in 1935 by California amateur Harold Lower and his father, Charles.

Lower's Nebula is perched 1° north-northeast of Nu (ν) Orionis. In the mirror-reversed view of my 130-mm refractor at 23×, the ½° nebula is a fairly faint, very fat C with a trapezium of stars nestled in the C's dark indentation and several lesser stars strewn upon the haze. The brightest trapezium star is the intensely hot, blue-white star (spectral type O7.5) thought to be the energy source for this huge emission nebula. A narrowband filter nicely enhances contrast between the backdrop of the sky and Lower's Nebula, which is softly wispy, and brightest in the south.

Star clusters and asterisms; double and newly emerging stars; planetary, cometary, emission, and dark nebulae — Orion has them all! Take a little time to discover some of Orion's unsung wonders before he slopes below your western horizon this spring. ✦

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

Little-Known Treasures of Orion

Object	Type	Mag(v)	Size/Sep	RA	Dec.
FSR 983	Asterism	9.3	4½′ × 2½′	5^h 23.1^m	+0° 38′
52 Orionis	Double star	6.0, 6.0	1.1″	5^h 48.0^m	+6° 27′
Cederblad 59	Cometary nebula	—	3′ × 2′	5^h 45.4^m	+9° 05′
NGC 2022	Planetary nebula	11.6	29″ × 28″	5^h 42.1^m	+9° 05′
Kohoutek 1-7	Planetary nebula	14.0	37″ × 36″	5^h 31.8^m	+6° 56′
Abell 12	Planetary nebula	12.0	37″	6^h 02.3^m	+9° 39′
NGC 2141	Open cluster	9.4	10′	6^h 02.9^m	+10° 27′
Lower's Nebula	Emission nebula	8.4	33′ × 29′	6^h 08.8^m	+15° 47′

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

The Galaxy Group AWM 1

Explore this little-known cluster in Cancer.

MARCH BEGINS the season for galaxy hunting in the Northern Hemisphere with a countless supply of targets stretching from Ursa Major in the north to Centaurus in the south. As a seasoned deep-sky observer, I generally chase challenging prey, but let's warm up with an eye-candy treat. **NGC 2903**, easily located 1.5° south of 4.3-magnitude Lambda (λ) Leonis, is an unusual starburst spiral containing "hot spots" of energetic star formation surrounding the nuclear region, and a central bar studded with scores of H II regions.

In my 18-inch Dobsonian this luminous galaxy extends 9′ × 4′, sloping north-northeast to south-southwest, with a slightly brighter bar running through the major axis. The center is sharply concentrated, with an intense, clumpy core due to the hot-spot regions. A faint H II knot sparkles at the south end of the bar, and a spiral arm emerges sweeping clockwise to the east. A brighter knot is visible near the north end of the bar and just beyond a fainter, ill-defined arm curves a short distance to the west. This arm structure carries its own catalog designation, NGC 2905, as both William and John Herschel assumed it was a separate adjacent nebula.

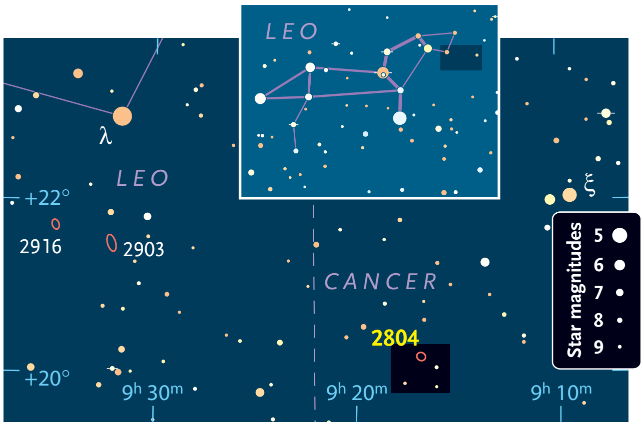
Now let's scoot 3.8° southwest, crossing into Cancer to the small galaxy cluster **AWM 1**. In 1977 this group caught the attention of Yerkes Observatory astronomers Elise Albert, Richard White, and William Morgan during a search for giant elliptical galaxies that reside outside their usual environment — the core of a rich Abell cluster. AWM 1 is the first entry in a short list of 7 galaxy groups meeting these criteria.

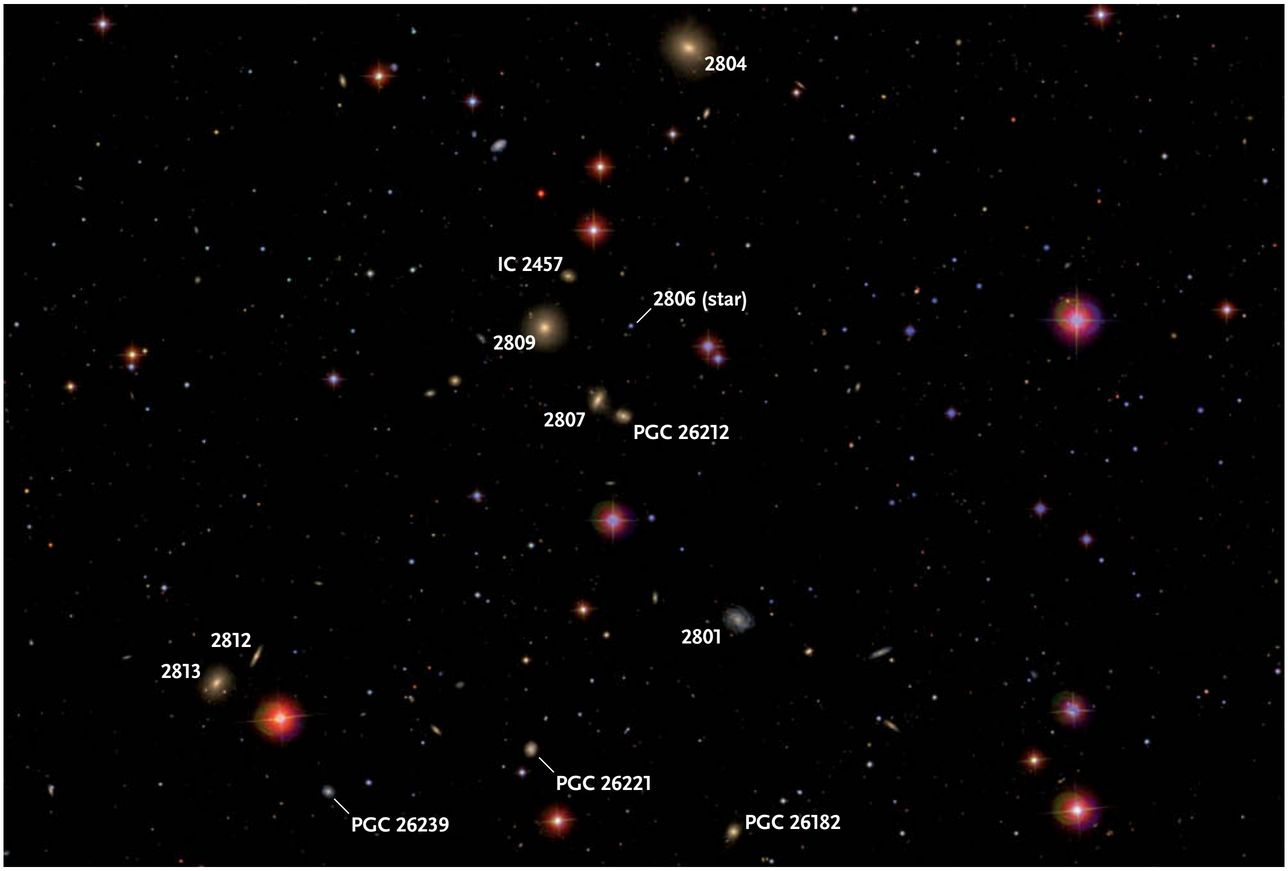
The 25′ field containing AWM 1 is packed with a dozen galaxies and several 9th- to 11th-magnitude stars. **NGC 2804**, the dominant 12.3-magnitude elliptical, is immediately recognizable in my 18-inch Dob at 100×. Bumping the magnification to 285× reveals a bright core embedded in a nearly uniform outer envelope extending 1.2′ × 0.9′.

An 8-inch scope should nab NGC 2804 along with slightly smaller, 12.8-magnitude **NGC 2809**, which lies about 9′ southeast. Its oval halo spans 0.9′ × 0.7′ and gradually increases to a small core punctuated by a faint, starlike nucleus. Several faint companions of NGC 2809

SHELDON FAWORSKI / SEAN WALKER

NGC 2903 is one of the most prominent barred spiral galaxies in the sky. The inner region is very bright, but the faint outer arms are rarely spotted through the eyepiece of a telescope.





The AWM 1 galaxy group is cradled by three 9th-magnitude stars (see the chart on the facing page). The field shown here is 35′ wide.

huddle nearby, including 16th-magnitude **IC 2457** just 1.6′ to the northwest. I missed this diminutive galaxy, possibly mistaking it for a dim star.

Just 2.5′ south-southwest of NGC 2809 lies 15th-magnitude **NGC 2807**, a weakly concentrated glow, perhaps 24″ × 20″. With careful viewing at 285×, a very close companion, **PGC 26212**, can be detected as a 15″ hazy knot just west of the south edge of NGC 2807. Several sources, including the *Uranometria 2000.0 Deep Sky Atlas*, misidentify PGC 26212 as NGC 2806.

So where's the real **NGC 2806**? John Louis Emil Dreyer, the compiler of the NGC, logged this object in 1876 using Lord Rosse's 72-inch speculum-metal reflector while making micrometric measurements of stars near NGC 2807 and 2809. His description reads: "A very faint star or considerably small, extremely faint nebula preceding (sky bad), forming an equilateral triangle with [NGC 2807] and [NGC 2809]." At precisely this position (2.4′ due west of NGC 2809) is a 15th-magnitude star that Dreyer thought might be nebulous in poor seeing conditions.

PGC 26226 is a 15″ feeble ember 5′ north-northeast of NGC 2809. Using averted vision, this 14th-magnitude galaxy wasn't difficult to snag 1.4′ southwest of an 11th-magnitude star. Now shift to the southeast side of the cluster where 9th-magnitude SAO 80743 resides.

This relatively bright star nearly overpowers **NGC 2813**, a 25″ pale glow just 2′ to the northeast. With direct vision, I can tease out a faint stellar nucleus within a tiny brighter core. NGC 2813 forms a close pair with 15th-magnitude **NGC 2812**, one of the more challenging members of AWM 1. Look for a ghostly, slender streak, 0.5′ × 0.15′, hiding in the glare of SAO 80743. Even tougher is 16th magnitude **PGC 26239**, a featureless 6″ dust mote 2.4′ southwest of the star.

I tracked down three more members to the west of SAO 80743. I picked up **PGC 26221** with averted vision as an 18″ × 12″ oval, just 40″ north-northwest of a 12.5-magnitude star. This galaxy forms the eastern vertex of an equilateral triangle with similar **PGC 26182** 6.0′ southwest and **NGC 2801** 6.7′ northwest. NGC 2801 is a uniform 25″ patch with a very low surface brightness. In 1865 Albert Marth discovered NGC 2801, 2812, and 2813 using a 48-inch f/9.4 equatorial at Malta but missed nearby PGC 26182, 26221, and 26239. Take a look and see how many of these challenging galaxies you can ferret out. ✦

__Steve Gottlieb__ has observed more than 10,000 deep-sky objects with his 18-inch Dob and other scopes. He will rotate authorshop of Going Deep with Ken Hewitt-White and other well-known deep-sky observers in future months.

By Alan MacRobert

The editors of Sky & Telescope *answer your questions about astronomy.*

Gravity, Shaper of Worlds

Why are stars and planets round?
— Gus Greaves, New York, NY

Their gravity pulls them into shape. But round is not always the shape that it pulls them into.

When something is as big and massive as a planet, rock deforms under its own weight and slowly squishes toward the planet's average level. It's seeking what physicists call a minimum-energy configuration, or "hydrostatic equilibrium." (On Earth an example is sea level.) Everything tries to go downhill, or fill up, to this level.

Given the strength of Earth's gravity, Mount Everest is about as high as any deviation from equilibrium can get before rocks deform and the deviation sinks under its own weight faster than mountain-building forces can push it up. Mars has a little less than half Earth's gravity. Therefore *its* highest mountain (Olympus Mons) is a little more than twice as high as Mount Everest.

There are three big exceptions to the overall roundness thing:

1. If a rocky body is smaller than about 500 miles (800 km) across, or if an icy body is smaller than about half that size, it won't have enough gravity to deform itself and reach hydrostatic equilibrium. That's why small bodies such as asteroids are lumpy and irregular. (An exception to *this* rule is when the asteroid is such a loose rubble pile that any jostling causes heights to settle and low areas to fill in. An example seems to be little round Dactyl, the 1-mile-wide moon of the larger, irregular asteroid Ida.)

2. If a planet or a star is spinning, the shapes of hydrostatic equilibrium are not spheres but flattened (oblate) ellipsoids. "Centrifugal force" (momentum) makes the body's equator bulge out. Earth is only 0.3% wider at the equator than at the poles, not enough to notice without instruments. But Jupiter is 7% and Saturn 11% wider at the equator. These planets are visibly flattened in a telescope. Fast-spinning stars are even more oblate: for Altair the ratio is more than 20%; for Achernar it's about 55%.

3. When an object closely orbits another ("closely" meaning compared to its own size), the different gravitational pulls on its near and far sides deform it into an egg shape or even a blunt teardrop with a point. At the point of the teardrop, material can and does fall off toward the other object. A ship sailing on the "sea level" of such a body could sail right off the edge of the world into space.

Stellar Burning Glass

How big a lens would you need to collect enough starlight to start a fire?
— Hector C. Johnson, Washington, DC

If you can set a piece of paper on fire with sunlight and a 3-inch magnifying glass, the answer is simple. The Sun shines at apparent magnitude –26.7. Sirius, the next brightest star in the sky, is magnitude –1.4, meaning that it's 1.3×10^{10} times fainter. So that's how much more light-collecting area you'd need: a telescope mirror 5.4 miles (8.7 km) wide. (A lens that big would absorb too much of the light, despite our cartoon.) This assumes that it concentrates the Sirius-light into the same size spot on the paper as the magnifying glass concentrates sunlight.

Another way to look at it: On a cold winter's night, Sirius casts about as much heat on your entire town as would warm your finger if it were all gathered there.

S&T: LEAH TISCIONE

A Tidal Secret

If the Moon and Sun look the same size in the sky, why does the Moon cause stronger tides?

— Richard Kilgallen, Alexandria, VA

Because the Moon is denser. Period. Any two objects showing the same angular diameter exert the same tidal force on Earth, if they have the same density. It does not matter how near or far they are. At all. (Assuming they're far compared to Earth's own diameter.)

Why? The *volume* of objects that have the same apparent diameter — in other words, the amount of stuff they contain — increases with the cube of their distance. But tidal force decreases as the cube of distance. So the two cancel out.

In fact the Moon and Sun are not the same density. The Moon averages 3.35 grams per cubic centimeter, and the Sun averages 1.41. So that's almost exactly the ratio of their tidal effects on Earth and its mobile oceans.

Worlds Without End, Amen

How many stars are there? How many planets?

— Timothy Timoshenko, Paducah, KY

Well, let's start with the easier part. Planet-formation specialists estimate that at least half of all stars are born with planets. Our solar system's tally of eight may be about normal. So a reasonable guess is that a few times as many planets exist as stars.

Now the hard part. Run-of-the-mill galaxies have about 10 billion to 1 trillion (10^{10} to 10^{12}) stars. Some 10^{11} galaxies are theoretically within range of the Hubble Space Telescope, though most of these are seen in the early universe when galaxies were smaller on average than they are now. Within our *event horizon* — the farthest we can see due to the Big Bang having happened only 13.7 billion years ago — the current best estimate is 3×10^{23} stars.

We cannot see beyond our horizon. Light from farther stars hasn't had time to reach us, and with the expansion of space speeding up, light from farther ones will eventually *never* catch up with us.

But what if you ignore the speed of light and imagine a God's-eye view of everywhere at once? Then the universe should be *much, much* larger. The inflationary-universe process — which accounts just right (so far) for all the details of how the Big Bang happened and pretty much everything else we know about cosmology — says the universe must be *at least* 10^{25} times wider than our event horizon. It also says that conditions should be about the same throughout this enormous volume, making for at least 10^{98} stars and planets.

Some inflation experts peg the inflated universe as being at least $10^{1,000,000,000,000}$ times wider than our event horizon, for at least $10^{3,000,000,000,023}$ stars and planets. More or less.

In fact, if you take inflation theory at face value, it predicts that space is infinite — in which case no number applies, no matter how large. But cosmologists and philosophers have no idea whether physically real infinities are possible.

For an examination of the four ways in modern physics that the universe, or multiverse, could be infinite or at least fantastically large, see Max Tegmark's landmark review at SkyandTelescope.com/tegmark. If your mind isn't blown yet, that'll do it.

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

The Stars from Space

How much brighter would the stars look from space than from the ground?

— Sherwood Waggy, Morris Plains, NJ

Not at all. Clear air absorbs or scatters only 15% to 25% of the light coming straight down from space. In other words, the air dims stars overhead by only about 0.2 magnitude. That's barely enough to detect by eye.

And consider this. When you look up from Earth there's nothing between your eyeball and the stars. An astronaut has to look through a helmet or a spacecraft window. Either is likely to absorb, scatter, and/or reflect as much light as a ground-based skywatcher loses to the atmosphere. ✦

Demystifying Flat Fields

Understanding the workings of flat-field calibration will greatly improve your CCD images.

Peter Kalajian

Whenever I'm in the company of other astrophotographers, I like to take a quick survey: how many of you are calibrating your images using flat fields? The results are not surprising. Invariably, few beginner amateur imagers raise their hands. After all, flat-fielding techniques seem to have a mystique associated with them, even among professional astronomers. This need not be so. With a bit study of the theory and practice, flat fielding can be understood and applied to great advantage by every imager.

Flat Fielding Explained

Every beautiful astrophoto begins with some basic calibration before the imager moves on to additional processing. Flat fielding is the part of this calibration that mitigates the effect of the CCD's pixel-to-pixel variation in sensitivity, vignetting in the optical system, and shadows created by dust on the components of the imaging system.

Let's imagine a perfect imaging system without hot or cold pixels, dust, and vignetting. If we expose this hypo-

S&T: DENNIS DI CICCO (2)

Producing the best astrophotos with CCD cameras requires more than just clear, steady skies. A series of calibration frames are needed to remove unwanted signal such as dark current and hot or dead pixels. One important calibration step involves flat-field frames, which correct for small variations of pixel sensitivity across the CCD detector, as well as vignetting in the optical system and dust shadows within the optical path. The pictures above show the results of an image processed without flat-field calibration (left) versus the same data processed with this important step (right).

thetical setup to a uniform light source, then every pixel in this image should have the same analog digital unit (ADU) or pixel value after exposure.

Of course, CCDs are not perfect, so pixel values in this "flat-field" image will vary. Just how much they vary tells us exactly how to modify each pixel in the image of an astronomical target to correct for the imaging setup's imperfections.

The entire calibration process can be summarized succinctly by the following simple relationship:

$$\text{Calibrated PV} = \frac{(\text{Raw PV} - \text{Dark PV})}{(\text{Flat PV} - \text{Dark PV})/(\text{Mean Flat PV} - \text{Mean Dark PV})}$$

This equation deals with pixel values (PV) from four separate images: a raw frame, a master dark frame made up of an average (or mean) of many dark frames of equal duration and temperature to the raw frame, a flat-field frame, and the flat field's own appropriate master dark frame taken at the same exposure length and temperature of the flat-field frame.

The equation's numerator is simply the raw exposure of an astronomical target corrected for any thermal "dark" signal due to non-photon-induced electrons in the CCD.

To understand the denominator, think back to the perfect CCD, where each pixel responded perfectly to the even illumination and needs no correction (in which case the denominator would have a normalized value equal to 1). Assuming the light source is perfectly uniform, the mean of all the pixel values in the flat-field image is a good approximation of the uniform pixel value from the perfect CCD. If a pixel value in the flat-field image is below the mean value, then it is "underreporting," while any pixels that have values above the mean are "overreporting."

Normalization

By dividing the flat-field pixel value by the mean of all the pixels in the flat-field image, we arrive at the normalized pixel value. A pixel that has a value equal to the mean will be normalized to 1, while a pixel that has a value less than the mean will be normalized to less than 1, and pixels with values above the mean will be normalized to more than 1. Any image-processing program that performs calibration takes care of this normalization automatically, but it's important to understand the process, as we'll see when we talk about how to get good flats.

Dark subtraction

It should now be apparent that master dark frames must be applied to both the raw image and the flat-field image in order for the pixel to be calibrated properly. Failure to subtract the dark current from a flat-field frame will

Author Peter Kalajian with his Flat Man XL, an electroluminescent panel used to record evenly illuminated flat-field images.

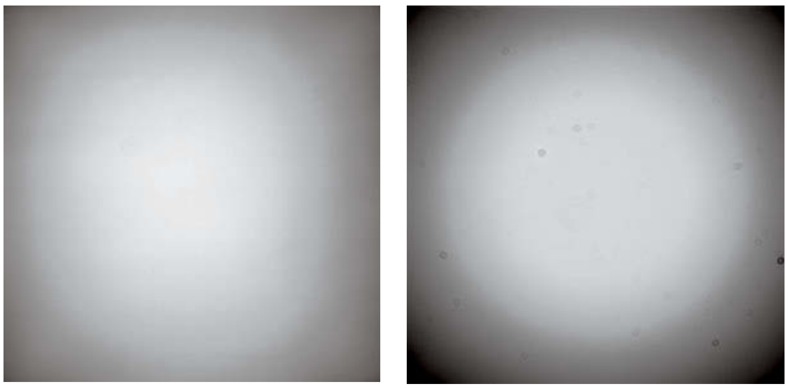
JACOB GERRITSEN

make the denominator incorrectly large, resulting in an improper correction to the raw image. Always dark calibrate your flats!

Characterizing Your CCD Camera

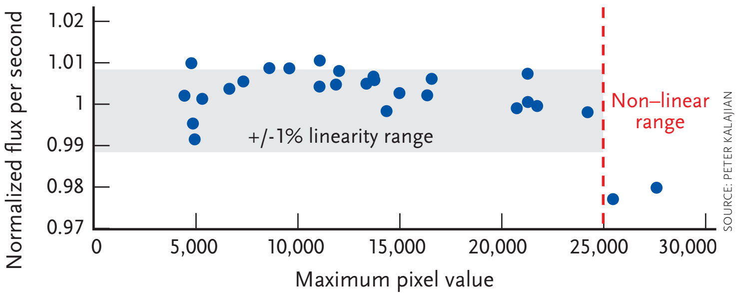
To reduce non-uniformity in your flats, make them with an exposure length that is long enough to eliminate the effects of the camera's shutter sweeping across the detector, but short enough to obtain pixel values within the linear range of the CCD detector. Exposing for at least two seconds takes care of most cameras' shutter latency problems, though larger chips may require longer exposures to truly mitigate its effect. How to decide on an upper-end limit depends on characterizing the linearity of your camera's detector.

Most anti-blooming CCD detectors do not have a linear response to photons across their entire dynamic range, and because of slight differences in each CCD, no two cameras will have the exact same range of linear response. My SBIG ST-2000 CCD camera becomes nonlinear when pixel values reach about 25,000, well below the 56,000 saturation limit. As such, I shoot for flat-field images with a maximum pixel value of about 24,000 just to be on the safe side. The consequence of using a flat-



S&T: DENNIS DI CICCO (2)

While both of these flat fields are suitable for calibrating their respective images, their different appearance arises from being recorded through a camera lens having very little vignetting, and the one at right being through a telescope.



Before shooting flat-field exposures, it's important for you to characterize your CCD camera. The author made this plot of a 9th-magnitude star near the zenith recorded with increasing exposures. As explained in the text, the plot shows that his CCD is linear until pixel values reach about 25,000. Flats must be exposed within the linearity range of a CCD detector.

field image with nonlinear response to photons is that the normalized pixel values will be too small, resulting in overcorrected images. Imagers using cameras with non-antiblooming detectors should shoot for pixel values close to full-well capacity (saturation), but avoid blooming. This ensures that the recorded flats take advantage of the majority of the CCD's entire dynamic range.

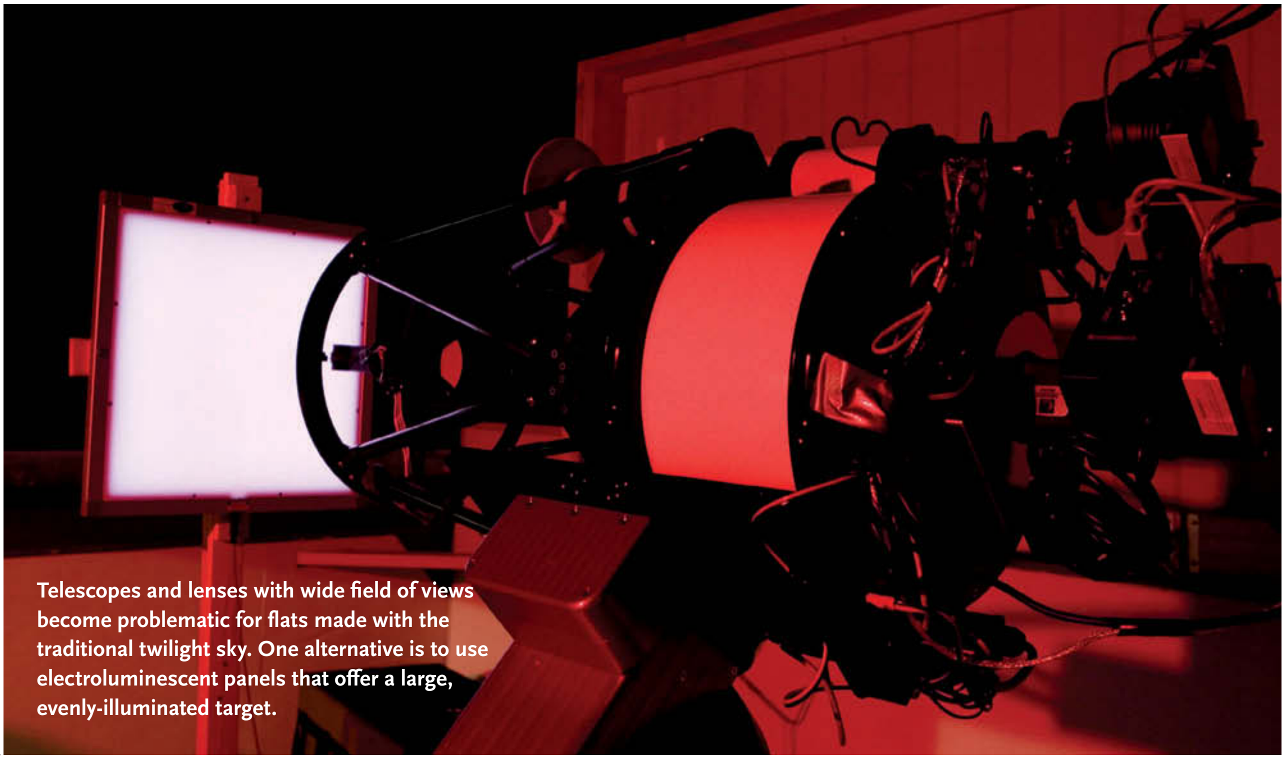
Characterizing the linearity of your CCD is fairly easy to do. A simple technique is to point the imaging system at a 9th-magnitude star near the zenith and take sets of five images at increasing exposure lengths until the star's image saturates (reaches the maximum pixel value). Using the photometry tool in your image-acquisition software, draw a box around the star, then measure the total flux and maximum pixel value inside the box for each image.

Enter the data into a spreadsheet and make a column that divides the total flux by the exposure time, which gives us the flux per second. Since the star's flux is constant over time (be careful not to choose a variable star), the flux per second will remain constant when it is within the linear range of the CCD, but will start to drop off as the CCD's anti-blooming gate kicks in. When this happens there will be a noticeable drop in flux per second and the CCD will be at the top of its linear range. Armed with this measurement, you should expose your flat-field frames to keep the pixel values below those where the flux per second starts to diminish.

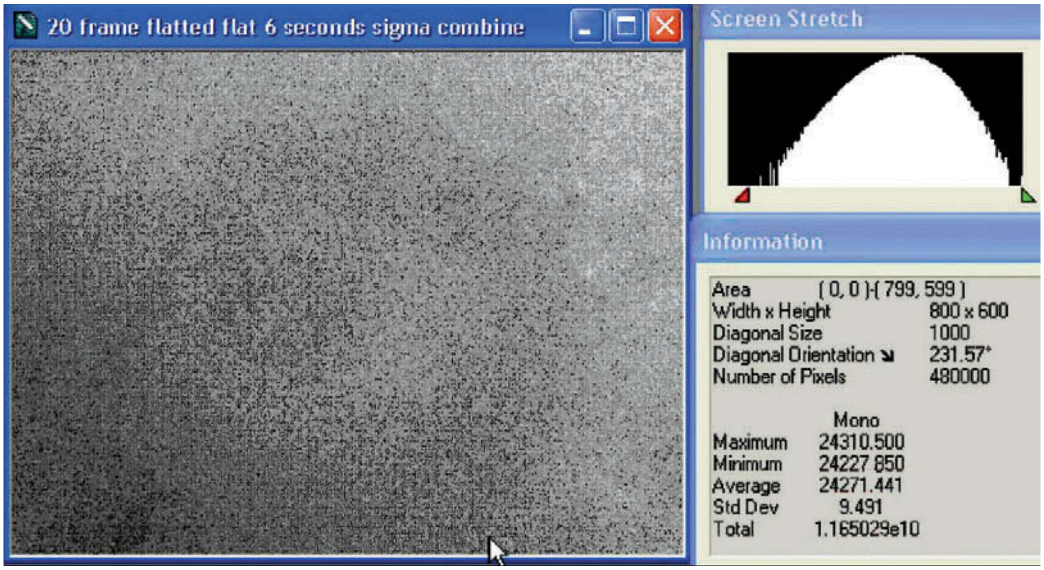
Uniform Illumination

This is the toughest part of the flat-field process; generating a perfectly uniform illumination source for your flat-exposures. Knowing when you have a uniform source is harder still.

Traditionally, imagers start out using the twilight sky as an illumination source. The trick is to point the telescope at a neutral point in the sky once the Sun has gone down enough so that the CCD detector does not saturate, but when there's still enough light to obtain good photon statistics. You have to race against the clock to get enough flat-field frames to assemble a master frame with enough of a signal-to-noise ratio so that the flat doesn't add noise



Telescopes and lenses with wide field of views become problematic for flats made with the traditional twilight sky. One alternative is to use electroluminescent panels that offer a large, evenly-illuminated target.



PETER KALAJIAN

Analyzing a "flatted flat," the author measured the uniformity of his electroluminescent panel and ST-2000M CCD camera using *MaxIm DL*. He found the image's average (mean) pixel value to be 24,271.441 and the standard deviation 9.491. His results yielded an impressive uniformity of 0.3%. Astrophotographers should shoot for a uniformity of 1% or less to achieve the best results when calibrating their exposures.

to your final image. To make matters worse, you have to do this for each of the filters that you plan to image through for the night.

These "twilight" flats can be good, especially in systems with small fields of view, using automated acquisition software that adjusts exposure time to compensate for changing lighting conditions. Wide-field imagers will be disappointed with twilight flats on the whole, since there's always some brightness gradient present in the sky. Some imagers mitigate the gradient by covering the telescope's aperture with some sort of diffuser, like a piece of translucent white acrylic or even a tee shirt stretched across the front aperture.

The problem with twilight flats is that you never know what the quality of the flat is like until it's applied to your image. Were there some high clouds that interfered with the evenness of illumination? Did you choose an appropriate neutral point in the sky? Were there gradients from ambient lighting in your neighborhood?

To avoid the problems with twilight flats, many imagers use artificial illumination. This can range from specially constructed light boxes placed over the telescope to white screens that are illuminated by multiple light sources. Recently, electroluminescent panels with the proper diffusion and power-supply regulation have shown great promise for producing evenly illuminated flats.

To evaluate the uniformity of illumination of your flat field, you can perform this simple test. Take an image of your illumination source, and then rotate your camera by 90° and take another image. Now calibrate the first image using your master dark and using the second image as the flat field. Doing this is essentially "flat-fielding a flat", so your resulting calibrated image should be completely uniform.

The best way to evaluate the uniformity is to check the histogram of this flattened flat. It should look like a symmetrical Gaussian distribution or bell curve, and the width of the distribution is proportional to the uniformity of illumination. To make a numerical estimate of uniformity, look at the standard deviation of pixel values in the image using the information window of your acquisition program. In a Gaussian distribution, 99.7% of all values lie within three standard deviations (commonly referred to by the symbol σ) of the mean on either side, so you can calculate the degree of uniformity of your flat field using this simple formula:

$$\text{\% of variation from uniformity} = \frac{100\% \times 2 \times 3\sigma}{\text{Mean pixel value of "flatted flat"}}$$

Our goal is to try to shoot for less than 1% variation from uniformity for best results. Non-uniform flats will result in poor image calibration where artifacts are still visible in the final image.

Proper flat-fielding techniques are critical steps in the image-processing workflow. With a little understanding of the math behind the calibration process, you can begin to hone your calibration techniques. Getting to know your CCD's linear range is an essential first step in the quest for good flat-field images. Astrophotographers who evaluate their flat-field illumination for uniformity may find that twilight flats aren't up to the task of wide-field image calibration, and those who use artificial light sources can check to see if their flat boxes are uniform. ✦

***Peter Kalajian** is president of Alnitak Astrosystems (www.alnitakastro.com). He teaches high-school math and science at the Watershed School in Rockland, Maine.*

GALACTIC CHANGE
Tim Khan
Known informally as the "Silver Dollar Galaxy," NGC 253 in Sculptor is among the brightest and dustiest spirals in the night sky.
Details: *TEC APO180FL refractor with an FLI MicroLine ML8300 CCD camera. Total exposure was 3½ hours through Baader color filters.*

◂ **THE COLORFUL LAGOON**

Roth Ritter

Located north of the spout of the "teapot" asterism within Sagittarius, M8 is among the brightest emission nebulae in the sky and is faintly visible without optical aid.

Details: *RCOS 10-inch Ritchey-Chrétien astrograph with an SBIG STL-11000M CCD camera. Total exposure time was 11 hours through Astrodon color filters.*

▴ **FAINT MOON RISING**

Stefano De Rosa

The gibbous Moon, only a few days away from full, rises alongside of the Basilica of Superga in Turin, Italy.

Details: *Canon EOS 1000D DSLR camera with zoom lens at 370 mm. Exposure was $^{1}/_{1,600}$ second at f/7.1, ISO 100.*

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.

▲ **OLD MOON AND EARTHSHINE**
Thomas Faber
A thin crescent Moon presented itself after a long night of observing for attendees of the Peach State Star Gaze in Crawfordville, Georgia.
Details: *Canon PowerShot SX100 IS digital camera. Snapshot captured on the morning of October 6, 2010.*

▶ **THOR'S HELMET**
Wolfgang Promper
NGC 2359 is a complex nebula formed by fierce stellar winds of a Wolf-Rayet star (at its center) interacting with a nearby molecular cloud.
Details: *16-inch f/8 Hypergraph with an FLI ProLine PL16803 CCD camera. Total exposure was 90 minutes through red, green, and blue color filters.* ✦

SKY & TELESCOPE Market Place

Your essential source for astronomical products

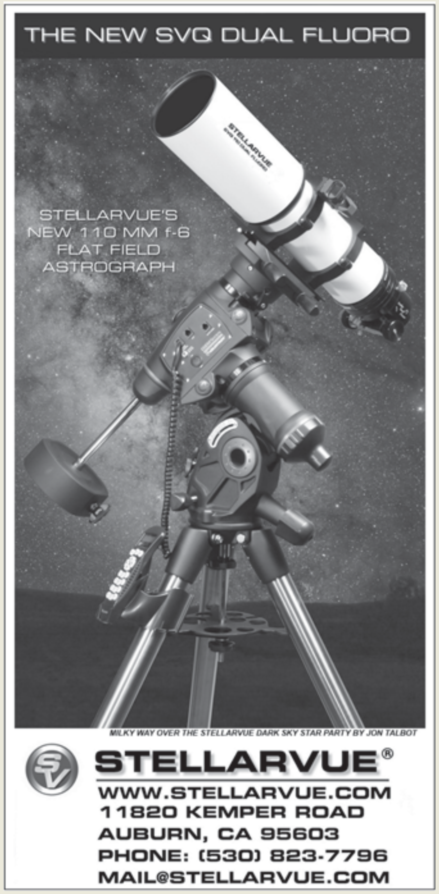
ACCESSORIES

ACCESSORIES

ACCESSORIES

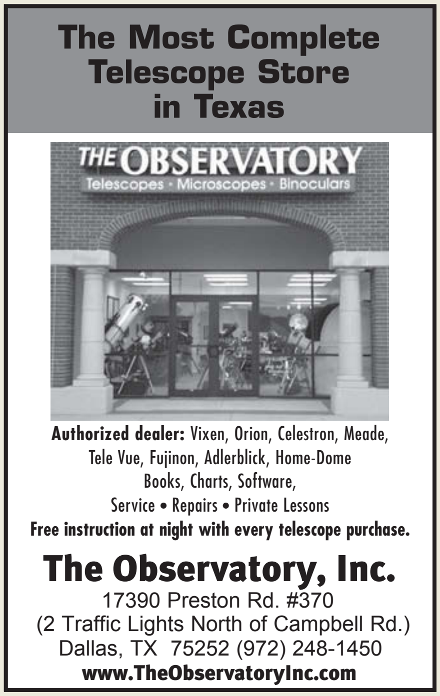
TELESCOPES

TELESCOPES



TELESCOPES

TELESCOPES



CLASSIFIEDS

PARADISE ASTRONOMY: 40 acres located in Southern Arizona. 40 x 80-ft insulated steel building, living area, garage, workshop, 200 amp service, excellent well, two septic systems, RV parking, $360K. 520-398-2722, W7UO@Hotmail.com.

ASTRONOMY CAMP STAFF: Yarger Observatory, YMCA Camp Eberhart, Michigan www.campeb.org or http://analyzer.depaul.edu/paperplate/astrocamp.htm Resume to Sandock.L@sbcglobal.net; 574-291-1121.

SUNDIALS: Whether you design, construct, research, restore, photograph, collect, teach, or just want to learn about sundials, join the North American Sundial Society. You'll find us at http://sundials.org. Click Join.

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: Beautiful new, fully furnished 3BR/2BA adobe home in Jack Newton's Arizona Sky Village (www.arizonaskyvillage.com). Observe under the darkest, clearest, most transparent skies in the Lower 48! Contact ikitzman@yahoo.com, 203-856-6864, www.arizona-dreaming.com.

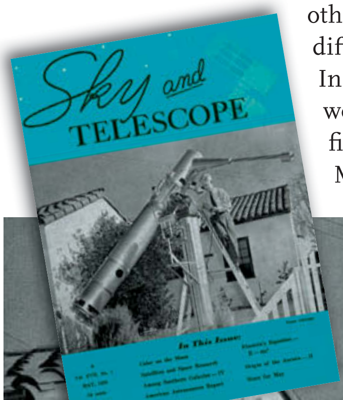
Index to Advertisers

How Good We Have It

If you think telescope prices are high today, consider what they were in 1958.

Filled with teenage enthusiasm, I raced for the mailbox. Yes, there's my May *Sky & Telescope*! The cover sported bold blue bands top and bottom with that distinctive *S&T* title across the top. Centered on the cover was a black-and-white picture of Clarence P. Custer with his 12½-inch reflector on a tall pier. "How could any amateur have a telescope that large?" I wondered. The year was 1958.

Recently I compared advertisements from that issue with the May 2010 *S&T*. I needed to multiply every 1958 price by a factor of 7.5 according to inflation tables. The first thing that strikes you is the color in today's *S&T* versus the black-and-white format of the older issue. But there are other big differences. In 1958 you wouldn't find Meade, Celestron, Tele Vue, or Orion. No Astronomics, Adorama, OPT, JMI, or Lumicon. There was no "Market Place" section in the back with cool gizmos. You certainly wouldn't find CCD cameras.



S&T ARCHIVES

The 1958 *S&T* included technical articles, but I preferred "Getting Acquainted with Astronomy" and "Gleanings for ATM's." I was grinding a 6-inch mirror, coached along by *S&T* plus the classic book *Making Your Own Telescope* by Allyn J. Thompson. Some of the 1958 ads were from Criterion selling "Dynascopes," Questar selling small tabletop Maksutovs, Stellar Scientific selling 6- to 16-inch reflectors, and Unitron selling high-drool-factor refractors.

To start my comparisons, I picked a 1958 6-inch Newtonian reflector with equatorial mount, motor drive, and setting circles. Criterion sold its 6-inch Dynascope for $405. Inflate that 7.5 times to get the modern price of $3,040. Stellar sold a similar scope for $420 ($3,150 today), and Astrola for $445 ($3,340). So the average inflated price of a 6-inch reflector was nearly $3,200.

In May 2010, Orion was selling a 6-inch reflector for only $420. Astronomics and other retailers were selling a Meade 6-inch LXD-75 for $600 and Celestron's 6-inch f/8 reflector on an equatorial mount for $500 (add a Go To capability for $300 more). The Konus 8-inch went for $670. What Schmidt-Cassegrains could you buy for around $3,200? Astronomics was selling the Celestron 11-inch CGEM 1100 HD Go To for $3,500. The Meade 10-inch LX200R with Go To capabilities on a fork mount went for $3,600.

In 1958 Edmund Scientific sold a 4-inch refractor for $247 ($1,850 today), but the real Cadillac refractor was made by Unitron. Four-inch Unitrons went for $465 ($3,500). The dream scope was that 6-inch Unitron decorating the May 1958 back cover for a "mere" $5,660. No, that's not inflated; inflated it's $42,450. Most amateurs dreamed of owning a Unitron refractor in those days — I know I did. Such a scope resides not far away and I hope to peer through its pricey optics in the near future. I'll compare it to my own $1,100 6-inch Celestron refractor on a Go To mount.

These comparisons heighten my enjoyment of the old *S&Ts*. As you thumb through modern *S&T* ads, you're seeing equipment and prices unimaginable back in 1958. No question: we really have it good today. ✦

***Albert Boudreau**, a retired aerospace engineer, now lectures on astronomy in Vermont, where he enjoys his own dark-sky observatory in Bridport.*

Space waits for no one.

Waiting to upgrade your observatory to join the hunt for dwarf planets, exoplanets, comets and minor planets? Or, yearning for the night your image becomes NASA's Astronomy Picture of the Day (APOD)? That wait's over. The Paramount ME can be yours right now. Its unrivaled precision, productivity and portability make the ME first and second choice among universities, research institutions and serious astronomers worldwide. What's really big news, for a limited time you can receive your ME immediately.* Your dreams come true today, not next year or the year after. Because, space waits for no one and it won't wait for you. bisque.com

ROBOTIC TELESCOPE MOUNT

ME

Paramount ME – $14,500.00
*Guaranteed to ship within 7 days.

shoot
the moon
The 8 EdgeHD that I received had the best star test I have ever seen, being on par with some expensive European catadioptric scopes I have owned... after searching long and hard for the Perfect SCT, I believe I have found it.
–Ed Moreno, EdgeHD 800 owner
SCHOTT
EDGEHD OPTICS
StarBright HIGH PERFORMANCE OPTICAL SYSTEM XLT
fastar COMPATIBLE
All-Star POLAR ALIGNMENT
CELESTRON®
Imagine the possibilities
www.celestron.com
Photo Courtesy of Andre Paquette
CELESTRON PREMIER SELECT DEALERS
OPT Telescopes 800.483.6287 www.opttelescopes.com
B&H Photo 800.947.9970 ww.bhphotovideo.com
Hands On Optics 866.726.7371 www.handsonoptics.com
Astronomics 800.422.7876 www.astronomics.com
Adorama 800.223.2500 www.adorama.com
High Point Scientific 800-266-9590 www.highpointscientific.com
Optics Planet 800.504.5897 www.opticsplanet.com
Telescopes.com 888.988.9876 www.telescopes.com
Focus Camera 800-221-0828 - www.focuscamera.com