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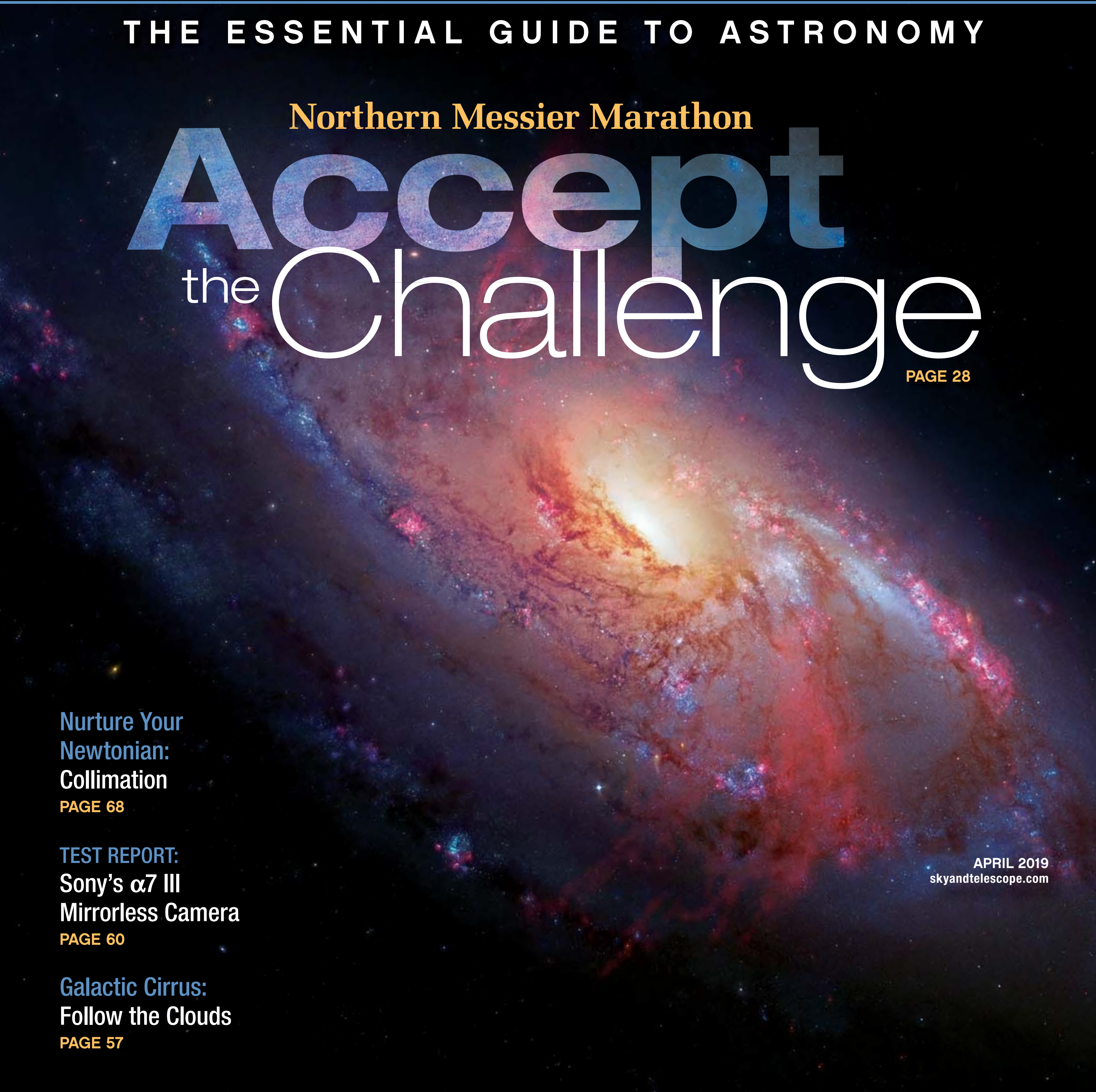
SKY & TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY



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ON THE COVER

Messier 106 delights in this mosaic of Hubble and ground-based observations.
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SKY & TELESCOPE (ISSN 0037-6604) is published monthly by Sky & Telescope, a division of F+W Media, Inc., 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. Periodicals postage paid at Boston, Massachusetts, and at additional mailing offices. Canada Post Publications Mail sales agreement #40029823. Canadian return address: 2744 Edna St., Windsor, ON, Canada N8Y 1V2. Canadian GST Reg. #R128921855. POSTMASTER: Send address changes to Sky & Telescope, PO Box 420235, Palm Coast, FL 32142-0235. Printed in the USA.

Southern Charms

SKY & TELESCOPE is Northern Hemisphere–centric for one reason and one reason only: Most of our subscribers reside on that half of the globe, primarily in the U.S. or Canada. That's why, when it comes to observing coverage, we focus largely on what you can see in northern skies and regretfully leave the southern heavens to our counterparts at *Australian Sky & Telescope*.

But sometimes we can't stand it anymore and just have to delve into those magnificent austral skies. All serious amateurs know that the firmament as seen from south of the equator has treasures unmatched in the North. The Carina nebula. 47 Tucanae. The Coalsack. The Magellanic Clouds. Northern Hemisphere observers *salivate* when they think of these and other southern treats.

In this issue, we head south to scrutinize several of them. In his "Constellation Close-up" on page 22, Tony Flanders reconnoiters two constellations practically synonymous with the southern celestial hemisphere: Centaurus, the Centaur, and Crux, the Southern Cross. Within those contiguous regions lie some of the most emblematic of southern wonders, from the Jewel Box, sprinkled with twinkling gems, to Omega Centauri, the most luminous globular cluster of all.

The jaw-dropping globular cluster 47 Tucanae

ESO / M.-R. CIONI / VISTA MAGELLANIC CLOUD SURVEY

On page 34, Javier Barbuzano investigates Alpha Centauri, the second star in our three-part series that began with Polaris in last month's issue. The binary at the heart of this three-star system is the brightest star in the entire sidereal vault after Sirius and Canopus. But that's not its greatest allure. The reason Alpha Cen draws observers like the Sirens did Odysseus's crew is that, at only about 4.3 light-years away, it's the closest stellar system to our own.

In part because of Alpha Cen's proximity, lots of cutting-edge science is taking place on it, as Barbuzano describes. One of the most compelling questions astronomers have is whether this neighboring system, which bears two stars that aren't all that different from our own, hosts any planets with liquid water on the surface — the *sine qua non* for life as we know it.

As a digestif to our southern repast, we offer an appraisal of an outreach event in South Africa during last July's total lunar eclipse that was almost *too* successful. Find out why in Carl Lindemann's story on page 84.

Incidentally, we're proud to report that *S&T* has subscribers across the Southern Hemisphere. As of mid-January, these include readers in Argentina, Australia, Brazil, Chile, Christmas Island, Ecuador, French Polynesia, Kenya, New Caledonia, New Zealand, Paraguay, Peru, South Africa, Uruguay, Zambia, and Zimbabwe. We hope you southern-half readers especially enjoy this month's foray into your sumptuous skies.

Peter

Editor in Chief

SKY&TELESCOPE
The Essential Guide to Astronomy

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

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Advertising Information: Tim Allen 773-551-0397, Fax: 617-864-6117. E-mail: tallen@skyandtelescope.com Web: skyandtelescope.com/advertising

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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., 201-634-7400.


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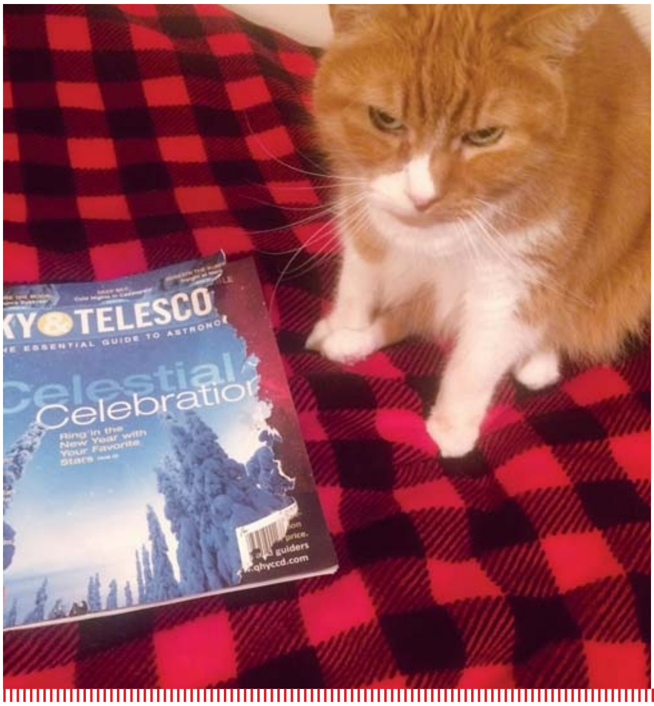


◀ You have to get up pretty early in the morning to keep Betsy from devouring the latest issue of *S&T*.

JOE BAUMAN

Hunger for Knowledge

This is what happens if Joe doesn't get out of bed fast enough when I want my cat food: I torture him by ripping up his *Sky & Telescope* until he gives in.

"Betsy" Bauman
Salt Lake City, Utah

Celestial Celebration

Thank you for publishing Scott Levine's "New Year's Eve Celestial Celebration" (*S&T:* Dec. 2018, p. 22). Although I'm a longtime subscriber, I've spent little time observing the sky in my severely light-polluted urban backyard. Before reading this article, I was ignorant of the Summer Triangle, Winter Hexagon, and the names and distances of the brightest stars in the sky. But motivated to identify the brightest stars visible on New Year's Eve and New Year's Day morning, I woke up early in November and December to familiarize myself with the Winter Hexagon in the western sky and spent time spotting Vega, Altair, and Deneb just after sunset. When the night of December 31 finally arrived, I was prepared and managed to spot all the stars on the list.

There are probably many others who, like me, love the evening sky in principle but are limited by circumstance or willpower to actually engage in observation. Articles like this give beginners an interesting objective to shoot for, and I'm grateful for the inspiration to begin serious observation at the age of 43.

Patrick Doherty
San Francisco, California

Catch a Speeding Star

Ken Croswell's fascinating article "The Fastest Stars Escaping the Galaxy"(*S&T:* Dec. 2018, p. 30) makes me wonder: Have we spied such stars that have actually "escaped" and are wandering about extragalactically? For that matter, do we know of any stars, or have any candidates, from another galaxy that have been captured by ours (analogous to the interstellar comet or asteroid we now call 'Oumuamua)?

Joel Marks
Milford, Connecticut

When I was in high school I envisioned stars wandering aimlessly among the galaxies, and I even coined a term for them: maverick stars. In 1982 I wrote to Dr. Carl Sagan asking, "Are there stars not belonging to any galaxy just drifting aimlessly through intergalactic space?" He was kind enough to respond but kept his answer very short: "Probably."

We've come a long way since 1982. But it was not until 2005 that the first "maverick" star was observed: a hypervelocity star. I had envisioned them more than 40 years ago; I just didn't realize how fast they'd be moving.

Ralph Fusco
Edison, New Jersey

Meet the Thuloids

The solar system contains planets, dwarf planets, and minor planets, all of which can possess moons. Minor planets within Jupiter's orbit are labeled asteroids, and these may be further subdivided into families according to their orbital or chemical characteristics. Orbiting the Sun in a 1:1 resonance with one of the major planets we have the Trojans, and between the orbits of Jupiter and Neptune there are a few Centaurs.

The latter two groups derive their names from Greek mythology. In classical times the Greeks had a name for a far-off, icy-cold, practically inaccessible place, namely Thule; a town in northern Greenland once had this name. In the solar system there is also a region that is distant, extremely cold, and difficult to reach: the space outside the orbit of Neptune, populated with many minor planets. I propose to name these *thuloids* after Thule, giving them a short yet classical name. One would no longer have to refer to them as trans-Neptunian objects (which is too long) or TNOs (which is an acronym).

The thuloids in the Kuiper Belt also contain families, one of which is the plutoids. The group of icy objects making up the scattered disk is as yet unnamed (not counting "scattered disk objects"), but *scythoids* comes to mind, after the Scythians, a martial people with whom the Greeks had a troublesome relationship.

Holger Nielsen
Støvring, Denmark

A Fount of Information

I recently celebrated my 60th year as an amateur astronomer. During my early formative years, issues of *Sky & Telescope* and the RASC *Observer's Handbook* were my reliable reference sources, coupled with periodic visits to the Fels Planetarium in my hometown of Philadelphia.

Over the past decade or so, I've been concerned about *S&T*'s seeming inability to publish issues with real amateur impact from cover to cover. Your December 2018 issue arrested that trend in spades. I maintain a monthly astro-logbook in which I record key information from my observations, imaging, and magazine perusal, and this issue proved to be a fount of such information. Bravo to your staff!

Frank Puzycki
Long Valley, New Jersey

Adieu to Sue

I was sad to read that Sue French is retiring from her column in your magazine. I remember that when it debuted, I was excited to see a column written by a woman. I had started subscribing to *Sky & Telescope* as a teenager in 1980 when the only women I saw in the magazine were models in the advertisements. But I've always thought *S&T* does a great job being inclusive and appreciate that you use gender-neutral language. And of course I was thrilled when Camille Carlisle and Monica Young began writing columns and became editors.

Thank you, Sue, for your wit and inspiration, for information about the objects to be viewed, and for pointing me to many deep-sky objects that I looked for with my Orion 6-inch Dob.

Caroline "Siffy" Torkildson
Grand Marais, Minnesota

Lost Kingdom

Re "The Great American Lunar Eclipse" (*S&T:* Jan. 2019), specifically the map on page 19:

I'm sure you must be as bored as we Brits with all the nonsense about us leaving the European Union, but it's only the EU we're leaving, not the Earth nor even our current location on it.

So, please, make sure you use a map which shows the British Isles (a small group of islands off the north coast of France) for your future lunar eclipse paths and timings. This isn't the first time you Yanks have "disappeared" your mother country, and whilst we may be small, we are not insignificant, particularly in astronomical terms.

Brian Martindale
Ledbury, United Kingdom

Peter Tyson replies: *We'd like to say we knew clouds would cover the entire archipelago on eclipse day, so why disappoint potential viewers? The truth is, the British Isles somehow went missing from that map, and we didn't catch it. Apologies from our side of the pond.*

FOR THE RECORD

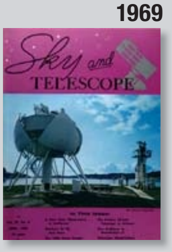
- In the lunar eclipse table (*S&T:* Jan. 2019, pp. 20–21), the entry for Total Eclipse Ends in the Eastern Standard Time zone should be 12:44 a.m.
- On the 2019 Skygazer's Almanac 40° North version, the hours from 5:00 p.m. to midnight on the timeline at the top should be labeled "Evening."

SUBMISSIONS: Write to *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140-3264, U.S.A. or email: letters@skyandtelescope.com. Please limit your comments to 250 words; letters may be edited for brevity and clarity.

75, 50 & 25 YEARS AGO by Roger W. Sinnott

1944

1969



1994

April 1944

Maksutov Scope "In the Moscow *News* of September 11th and 22nd, 1943, [we read:] A new invention, not generally known as yet, will be the subject of a paper by Professor D. Maksutov. This scientist has designed a new type of reflector telescope with a correction lens, which, according to [conference organizer A. A.] Mikhailov, will effect a revolution in astronomical optics. Thanks to it, telescope lengths may now be reduced nearly eight times. Moreover, the quality of the images is even improved.

"The reflectors proposed by Professor Maksutov are also said to be easier to produce than existing ones."

These claims weren't too exaggerated, at least for small apertures. Soon after the war, Maksutov's design appeared in the popular 3.5-inch Questar, and in 1956 a Maksutov craze took hold among amateur telescope makers. One of their mentors, John Gregory, engineered the 22-inch Maksutov at the Stamford Observatory in Connecticut.

April 1969

Pulsar Flashes "One of the most important events in recent astronomy has been the discovery of strong pulses of light coming from the pulsating radio source NP 0532 inside the Crab nebula. . . . At Lick Observatory in California, J. S. Miller and E. J. Wampler carried out special observations on the evening of February 3rd to determine more accurately the position of the optical flashes. At the coudé focus of the 120-inch reflector, a Westinghouse television camera used an image intensifier coupled to an SEC camera tube. . . .

"In all, 46 photographs were obtained from the video tape, which confirm that the southwest star of the double is in fact the seat of the light flashes."

Back in the 1960s, a secondary electron conduction tube and TV camera were a small step on the road to the CCD imagers of today.

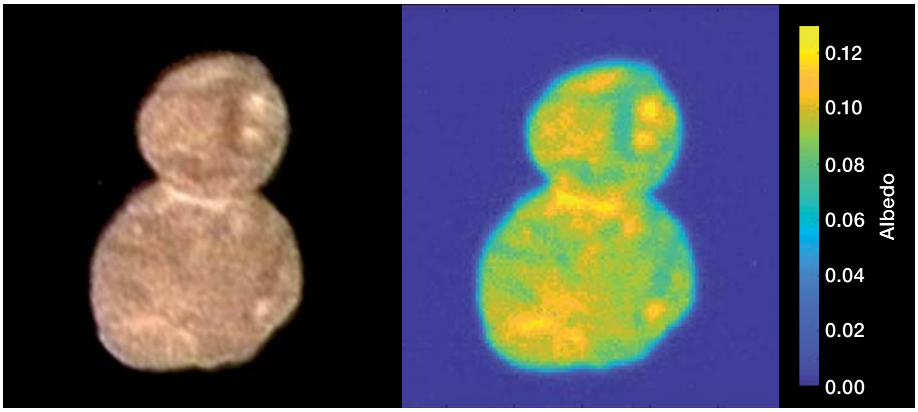
April 1994

Hubble's Fix "When space shuttle *Endeavour* touched down at the Kennedy Space Center in predawn darkness last December 13th, astronomers . . . had no idea whether the corrective optics installed to sharpen the telescope's vision actually worked. . . .

"The suspense finally ended on January 13th, when the first corrected images from Hubble were unveiled at a crowded press conference held at NASA's Goddard Space Flight Center. . . . 'The trouble with Hubble is over!' [Maryland senator Barbara] Mikulski declared. 'Now we know that NASA has the right stuff.' . . . These words rang especially sweet coming from her. In June 1990, upon learning that Hubble couldn't be focused properly because of a manufacturing defect, Mikulski had . . . cast grave doubts on the future of space astronomy at NASA."

SOLAR SYSTEM

First Views of Distant Object "Ultima Thule"



▲ *Left:* This view of 2014 MU_{69} combines a detailed black-and-white image (140 m per pixel) with a lower-resolution, enhanced-color image using blue, red, and near-infrared frames. *Right:* Overall, the two lobes are roughly as dark as the Moon's maria, though the "neck" that joins them is both brighter and less red than elsewhere.

AT 5:33 UNIVERSAL TIME on January 1st, NASA's New Horizons spacecraft successfully flew past the tiny Kuiper Belt world 2014 MU_{69}, better known by the nickname "Ultima Thule" (pronounced *UL-ti-muh THOO-lee*, meaning "beyond the known world"). The highly anticipated event occurred some 6.6 billion km (4.1 billion miles) from Earth and 3½ years after the spacecraft's historic encounter with Pluto in July 2015.

In the days and weeks following the flyby, the slow trickle of observations radioed by the spacecraft's 15-watt transmitter have morphed 2014 MU_{69} from a 26th-magnitude blip barely observable by the Hubble Space Telescope into a tiny, colorful, and intriguing two-lobed object. It's made of two roundish worlds nestled against each other, with one lobe somewhat larger than the other, and has a combined length of 33 km (21 miles). Both lobes are dark, slightly reddish, and mottled with brighter and darker markings.

This "snowman" appearance was expected — that shape had been inferred from a challenging but successful ground-based effort to record the object's passage in front of a star in July 2017 (*S&T:* Nov. 2017, p. 9). Moreover, astronomers now realize that many objects in the "classical" Kuiper Belt are also binaries. These objects, like 2014 MU_{69}, lie 40 to 50 astronomical units from the Sun and have roughly circular, low-inclination orbits.

This object became New Horizons' post-Pluto target simply because the spacecraft could reach it. Nevertheless, it offers a rare look at the origins of the solar system. Dynamicists suspect that this body formed directly in the frigid fringe of the solar nebula 4½ billion years ago and has remained largely unchanged ever since.

The two lobes rotate around as a single structure in roughly 15 hours, a relatively slow spin that doesn't create nearly enough centripetal force to fling them apart. They're "soundly bound" in a structural sense, notes investigator Jeffrey Moore (NASA Ames), though they're essentially "resting on each other."

The larger globe of 2014 MU_{69} (dubbed "Ultima") has roughly three times the volume of its companion ("Thule"). They probably consist primarily of ice, but their surfaces are actually quite dark, reflecting between 6% and 13% of the weak sunlight striking them. The reddish hue, thought to arise from complex organic compounds pounded for eons by space radiation, matches that of other low-inclination Kuiper Belt objects.

But the narrow "neck" joining the two globes is both the brightest and the least red of the surface seen so far. This could mean that it has a different composition, or perhaps it's where small particles have "rolled" down steep slopes toward the object's center of mass.

Still to come are observations taken when the spacecraft passed closest, at a distance of just 3,535 km. Specifically, a series of images taken by the Long Range Reconnaissance Imager (LORRI), essentially a 20.8-cm f/13 telescope, could reveal details on the two lobes' surfaces down to about 17 m across.

■ **J. KELLY BEATTY**

Dying Stars Make Glowing Serpent

Astronomers discovered two dying stars spinning out coils of dust 8,000 light-years away. Although the system is officially known as 2XMM J160050.7-514245 (*left*), its snake-like appearance earned it the nickname "Apep," after the serpentine god of ancient Egypt. At Apep's center is a duo of massive Wolf-Rayet stars, which are blowing off their outer layers before they explode as supernovae. (The pair is unresolved at center; to their upper right is a fainter companion star.) The snake-like shape, which stretches almost half a light-year wide, arises as one of the stars carves its way through the other's stellar wind. While one of the stars blows out material at a swift 3,400 km/s (7.6 million mph), the dusty pinwheel is expanding more slowly at only 570 km/s. That star might be launching dual winds, one fast and one slow, a feat indicating that it's spinning almost fast enough to fly apart. Apep might be an example of what happens before long-duration gamma-ray bursts, thought to be massive stellar explosions. The results appear in the November 19th *Nature Astronomy*.

■ **JOHN BOCHANSKI**

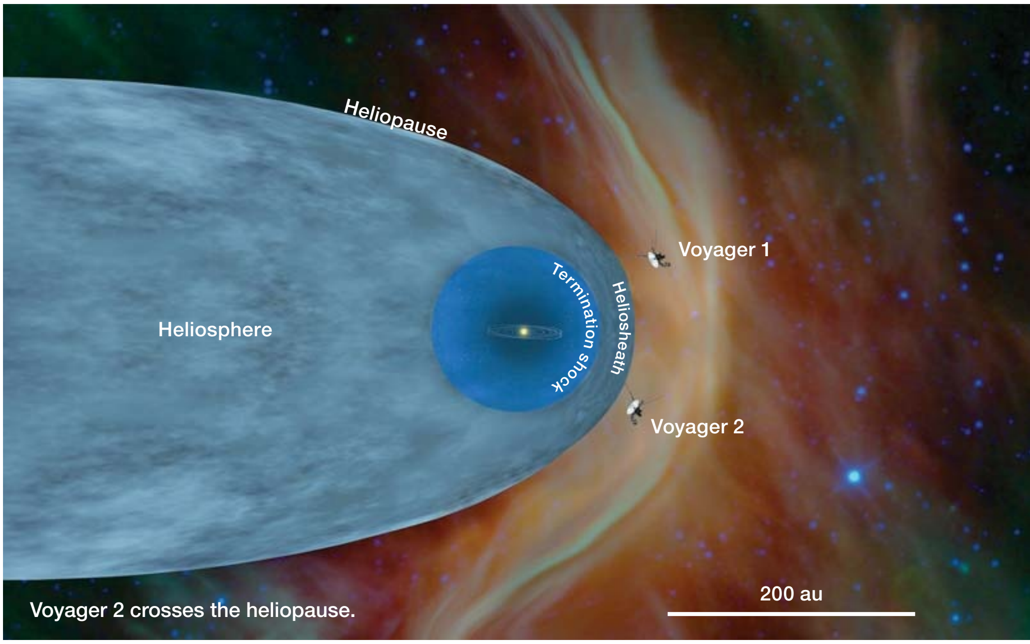
ULTIMA THULE: NASA / JHU-APL / SWRI; COILS OF APEP: ESO / CALLINGHAM ET AL.

SOLAR SYSTEM

Voyager 2 Enters Interstellar Space

VOYAGER 2 HAS BECOME the second probe to break through to interstellar space, mission scientists announced December 10th at a meeting of the American Geophysical Union in Washington, D.C.

A plasma detector onboard Voyager 2 recorded a sharp decline in the speed of the solar wind on November 5th. Around the same time, the spacecraft also saw a sharp uptick in cosmic rays — high-speed atomic particles that whiz around the galaxy — as well as an increase in the ambient magnetic field. This confluence of events gave mission scientists confidence that the probe had finally broken out of the *heliosphere*, a bubble of space surrounding the Sun in which the solar wind reigns supreme.



Voyager 2 crosses the heliopause.

This marks the second time that a spacecraft has crossed this threshold. Voyager 1 crossed the heliopause in 2012 (*S&T:* Dec. 2013, p. 10). However, its plasma detector had stopped working back in 1980. Now, with Voyager 2 joining its twin in interstellar space, scientists will be able to obtain the first direct measurements of the ionized gas that drifts between the stars. Voyager 2 will also provide a second measure of the flux of galactic cosmic rays that impinges on the solar system. Mission scientists anticipate another five to 10 years of operations for the aging probes.

■ **CHRISTOPHER CROCKETT**

MOON

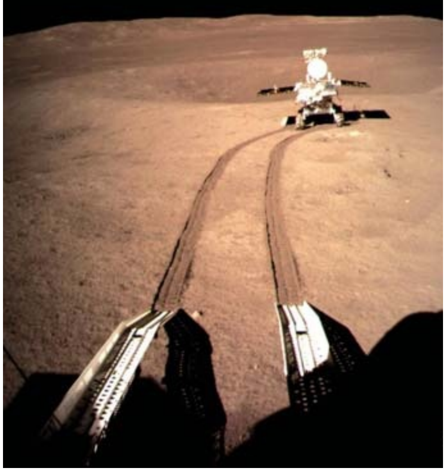
Chang'e 4 Lands on Lunar Farside

THE CHINESE SPACECRAFT Chang'e 4 (named for the Chinese Moon goddess) has landed softly on the farside of the Moon — the first mission to accomplish this milestone.

The spacecraft launched on December 7, 2018, and touched down in Von Kármán crater on January 3rd at 2:26 UT. The 180-km-wide (110-mile-wide) crater is one of the few flat areas within the South Pole-Aitken Basin. This basin was created in one of the solar system's largest impacts, which might have smashed through the crust and exposed the lunar mantle. Exploring this region may reveal information about the formation and structure of the Moon. The lander snapped images of the terrain around it, then the Yutu 2 rover (Chinese for "jade rabbit") rolled down its ramp later that same day.

The spacecraft landed around local lunar sunrise, giving the solar-powered crafts roughly two weeks of illumination before sunset in late January; heating units keep both of them warm during lunar night. Throughout the three-month mission, the Queqiao (Chinese for "magpie bridge") orbiter will relay the probes' data from its halo orbit around the L2 Lagrangian point 60,000 km past the Moon.

Yutu 2, from the Chang'e 4 lander



In addition to examining its new home with a battery of instruments, Chang'e 4 carries a small container with three species of plant seeds, fruit fly larvae, and yeast. This student experiment will measure how an enclosed mini-ecosystem fares in low gravity. The lander will also carry out low-frequency radio observations. The Chinese space agency has committed to an open data policy for this mission, though it's not yet clear how the data will be released.

Later this year, the heavier Chang'e 5 lander and sample return capsule is expected to join its smaller sibling on the Moon. However, this mission still awaits a return to flight for the Long March 5 heavy-lift rocket.

■ **DAVID DICKINSON**

See videos of Chang'e 4 and Yutu 2 at https://is.gd/Change4landing.

HELIOPAUSE: NASA / JPL-CALTECH / GSFC; YUTU 2: CNSA

GRAVITATIONAL WAVES

LIGO & Virgo Discover Four More Black Hole Collisions

▲ Illustration of a black hole duo

A RE-ANALYSIS OF DATA from the Laser Interferometer Gravitational-wave Observatory (LIGO) and the Virgo interferometer in Italy found four new events, bringing the total number of gravitational-wave events detected so far to 11. The tally includes the most distant and most powerful black hole merger yet discovered.

LIGO and Virgo announced the new events, designated GW170729, GW170809, GW170818, and GW170823, at a gravitational-wave conference on December 1, 2018. The first of these became the most massive merger detected to date — and the most distant too, as the signal had traveled 5 billion years to Earth. To create the signal, two black holes weighing in at 34 and 51 solar masses had coalesced into an 80-solar-mass monster, unleashing the energy equivalent of five solar masses as gravitational waves.

The finds help characterize the origin of this population of binary black holes and the frequency with which they merge. The collaboration has used the detections to date to show that between 10 and 100 binary black holes merge per year in a volume 3 billion light-years on a side. This number appears to grow with increasing distance, which would be expected since stars formed more rapidly in the past than now.

However, while the black holes are all of stellar mass and have likely supernova origins, GW170729 might pose a challenge to stellar evolution models, which have trouble producing hefty black holes. Then again, uncertainties in the mass measurements of the progenitors mean the signal is still consistent with current models.

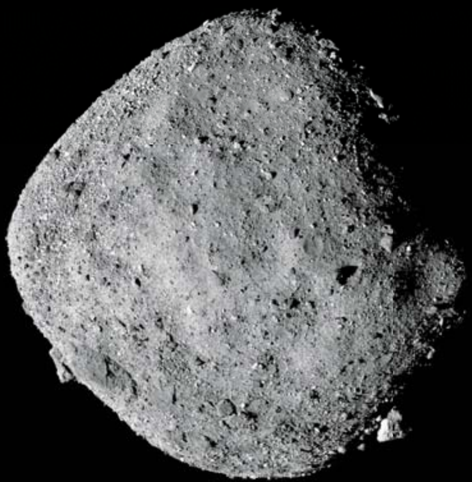
In addition to the four new statistically significant finds, the LIGO/Virgo Collaboration also published a list of 14 "marginal event candidates." The collaboration will release all data from the second observing run in February 2019. Meanwhile, all three gravitational-wave detectors are being upgraded for a new simultaneous observing run beginning in April 2019. Given the instruments' improved sensitivity, scientists expect to find at least a few events per month.

■ GOVERT SCHILLING

To learn more about what LIGO and Virgo are teaching us about black hole spin, visit https://is.gd/LIGOspins.

ASTEROIDS

Osiris-REX Arrives, Finds Hints of Ancient Water



▲ Bennu, as seen by Osiris-REX

NASA'S OSIRIS-REX arrived at asteroid 101955 Bennu on December 3rd and kept pace with the asteroid for several weeks before entering into orbit on December 31st. Now, the spacecraft is mapping Bennu from about 730 meters (2,400 feet) above its surface.

Even before it entered into orbit, Osiris-REX's preliminary surveys had led to the detection of hydrated minerals on Bennu's surface, suggesting that the asteroid's larger parent body once hosted water. Amy Simon (NASA Goddard) announced the results December 10th at a meeting of the American Geophysical Union in Washington, D.C.

Two spectrometers onboard Osiris-REX picked up the presence of *hydroxyls*, molecules that contain oxygen and hydrogen atoms bonded together. The mission team suspects that these molecules are locked up in clay minerals, created in interactions with liquid water or water vapor.

Bennu itself is too small to have ever hosted liquid water. However, researchers think that the roughly 500-meter-wide (0.3-mile-wide) space rock is actually a chunk knocked off a much larger asteroid long ago. The find suggests that water existed at some point on Bennu's home world.

Most of the next year is dedicated to mapping and scanning Bennu's surface, surveying for the perfect spot from which to grab some material. Then, around July 2020, the real excitement begins, as Osiris-REX moves in for a series of sampling maneuvers. The spacecraft will return the sample to Earth, with a planned homecoming in 2023.

■ DAVID DICKINSON & CHRISTOPHER CROCKETT

BLACK HOLES: LIGO / CALTECH / MIT / SONOMA STATE (AURORE SIMONNET); BENNU: NASA / GODDARD / UNIV. OF ARIZONA

EXOPLANETS

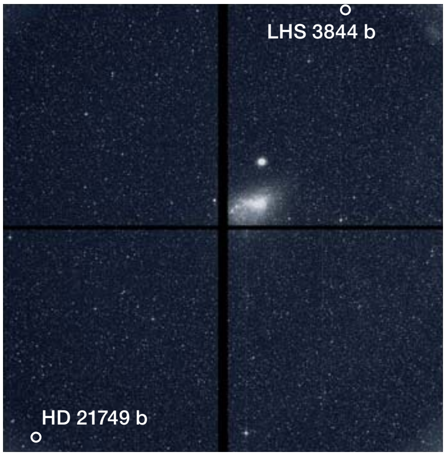
NASA's TESS Mission Announces New Planets

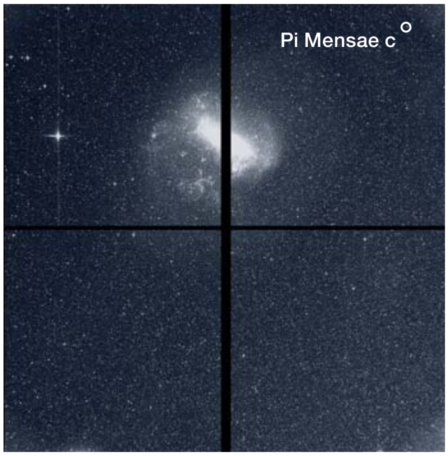
ASTRONOMERS ON NASA'S Transiting Exoplanet Survey Satellite (TESS) team have announced the discovery of eight confirmed planets, as well as more than 300 exoplanet candidates.

Launched in April 2018 (*S&T:* Aug. 2018, p. 8), TESS began science operations last July, searching for planets around 200,000 of the nearest stars. At press time, the mission had monitored six sky sectors for 27 days apiece.

The new finds, presented at the American Astronomical Society meeting on January 7th, use only the first three months of observations. While the catalog paper is still forthcoming, the team provided details on three of the smallest confirmed planets:

▼ The locations of three confirmed small planets are labeled in sections from TESS's first-light image. (The Small and Large Magellanic Clouds appear at left and right, respectively.)





Pi Mensae c (*S&T:* Jan. 2019, p. 12) is a super-Earth about five times Earth's mass that circles its Sun-like star in six days. A previously discovered gas giant accompanies it on a highly elongated six-year orbit.

LHS 3844 b is a hot, slightly more-than-Earth-size planet that circles its red dwarf star in just 11 hours.

HD 21749 b, the newest discovery, is a sub-Neptune that's three times Earth's girth but 23 times its mass. It's denser than Neptune, but not so much that it's rocky; astronomers suspect it has a thick, heavy atmosphere. The planet is on a 36-day orbit and was discovered with additional transit data from ground-based telescopes.

As Principal Investigator George Ricker (MIT) points out, the spacecraft is in a stable orbit, its cameras are performing beautifully, it has oodles of propellant left, and the only moving parts are four momentum wheels that should last decades. As long as the mission continues to receive funding, there's no reason TESS can't keep on keeping on for at least another decade.

■ MONICA YOUNG

IN BRIEF

Most Distant Solar System Object Discovered

Nicknamed "Farout," the object provisionally designated 2018 VG_{18} currently orbits the Sun somewhere between 115 and 125 astronomical units. That's more than three times farther out than Pluto is, on average, and more distant than any other objects known. Scott Sheppard and colleagues discovered the object in November using the Subaru telescope in Hawai'i. Graduate student Will Oldroyd (Northern Arizona University) joined the team in early December for further observations using one of the Magellan telescopes in Chile. The additional images enabled the scientists to measure the object's motion against background stars, giving its distance. The team found Farout as part of their ongoing search for Planet X, an as-yet undetected world thought to be shaping the orbits of several distant solar system objects (*S&T:* Oct. 2017, p. 16). However, depending on the shape of Farout's orbit, it could take another one to three years of observations before the team nails down its orbital parameters and determines whether it, too, has been influenced by the putative Planet X.

■ MONICA YOUNG

M77 Supernova Discovered

On November 24th the DLT40 survey, conducted with a 0.4-meter telescope in Chile, picked up a 15.4-magnitude supernova in M77, a bright, barred spiral galaxy in Cetus. Designated 2018ivc, the new supernova brightened only briefly; intervening dust dimmed and reddened its light. It first appeared as a tiny pinprick of light 8.7" east and 16.1" north of the center of the galaxy along the edge of the bright inner disk. Spectroscopy revealed a Type II supernova, whose blast sent debris flying outward at some 13,500 km/s (30.2 million mph). This is the first recorded supernova in M77.

■ BOB KING

White Dwarfs' Crystal Cores

White dwarfs face a crystallized fate, astronomers report in the January 10th *Nature*. When the European Space Agency's Gaia satellite revealed precise distances, and thus luminosities, to 1.7 billion stars last year (*S&T:* Aug. 2018, p. 9), it also measured these properties for 200,000 white dwarfs — a thousandfold increase compared to what was previously available. Pier-Emmanuel Tremblay (University of Warwick, UK) and colleagues placed 15,000 of the nearest white dwarfs on a diagram that plots magnitude against color, which serves as a proxy for temperature. The white dwarfs fall exactly where certain evolutionary models had predicted. These models suggest that, as white dwarfs cool, their cores experience a phase transition. When white dwarfs first form, they pack so much matter into so small a space that the atomic nuclei join together into a kind of fluid, while the electrons become unbound into a gaseous haze. But once white dwarfs cool below 10 million degrees, the nuclei fluid solidifies. Moreover, the nuclei release heat as they settle into an ordered structure, so the crystallization actually delays the white dwarf's overall cooling. Cooling resumes once the core is fully solid. Based on these findings, Tremblay predicts that the Sun will crystallize, too, in about 10 billion years' time.

■ MONICA YOUNG

NASA / MIT / TESS

WHIRLPOOL GALAXY The grand spiral of Messier 51 sports dramatic dust lanes and pink star-forming regions.

Spendthrift S

Spirals are the most spectacular of galaxies. Like a giant vortex in space, a spiral galaxy spins through the cosmos, its mighty arms squeezing gas and dust into newborn stars. Blue supergiant stars and pink clouds of ionized hydrogen gas sparkle in the spiral arms, where the occasional flash of a supernova explosion casts newly minted chemical elements into the galaxy.

These magnificent galaxies lend grace and beauty to the night. Moreover, they work hard to create new light. Five out of every six stars born each year are born in spiral galaxies, some in normal spirals like the Whirlpool, others in barred spirals like the Milky Way.

Yet these same exquisite galaxies face an immense problem. As spiral galaxies spawn new suns, they exhaust the very gas and dust that enable them to be spirals in the first place.

The Spiraliferous Period

The modern universe abounds with so many spiral galaxies that it's easy to imagine they will endure forever. About 70% of the bright galaxies within a billion light-years are spirals. Most galaxies in Charles Messier's great catalogue are spirals. And the Local Group's three most luminous galaxies — Andromeda, the Milky Way, and M33 — are all spirals. Just as geologists call the time when much of our planet's coal formed the Carboniferous Period, so we might call the present time the Spiraliferous Period.

Spiral galaxies can't last unless they find more gas. Gas is not just a galaxy's means for making new stars; it's also essential for spiral structure.

This spiral-spangled period took a long time to start, however, in part because the universe's first galaxies were too small to spin fast. "Spirals tap rotational energy," says astronomer Bruce Elmegreen (IBM Research Division). "Low-mass galaxies can't form spirals because they rotate too slowly." Even after galaxies grew massive enough to spin fast, spirals remained rare for billions of years after the universe's birth. "You don't get spirals then, because everything's very turbulent," he says. "The galaxy is accreting gas like crazy, which stirs it, and it's also got a high star-formation rate, which stirs it." This vigorous mixing acted like a kitchen blender, preventing spiral structure. Galaxy collisions in the crowded early universe added still more turbulence.

▲ **WAFER** This Hubble image of NGC 5866 in Draco reveals the galaxy's edge-on disk. From this perspective, the dust lane and blue stellar disk slice through the central bulge.

Turbulence is a spiral galaxy's foe, for a spiral needs tranquility. In a tranquil fast-spinning galaxy, stars and gas race around the galaxy's center, but they do so slowly relative to one another. They have what astronomers call a *low velocity dispersion*, much lower than the galaxy's rotation speed. So the stars and gas don't drift far above or below the galaxy's plane, and the disk stays thin. That keeps the stars and gas close together, making the disk dense.

"You want high density, so that gravity is important," Elmegreen says. "Gravity does all the action to make spirals." In such a dense environment, gravity has the chance to enhance concentrations of stars and gas that happen to develop in the disk. These excesses feed on themselves as their gravity pulls in additional stars and gas. The galaxy's rapid rotation shears this material, whipping it into a spiral pattern just as stirring cream into coffee does. But too much turbulence in the coffee — or the galaxy — would blur the spiral and ruin the beautiful pattern.

The farthest known spiral galaxy, Abell 1689 B11 in the constellation Virgo, makes the case for tranquility. The galaxy has a redshift of 2.54, which means its light has traveled for 11.2 billion years to reach us, so the spiral existed when the universe was only 2.6 billion years old. "No one was expecting to see spiral arms at this redshift," says Tiantian Yuan (Swinburne University of Technology, Australia), who calls the spiral a "weirdo." By good luck, it resides in an unusually quiet neighborhood, with no other galaxies to jostle it, so it sports a thin disk and thus sprouted spiral arms long before its peers.

Elmegreen estimates that spiral galaxies emerged in earnest 9 to 10 billion years ago, after the universe had settled down. Today spirals are flourishing. They now dominate most galaxy groups and garnish the outskirts of galaxy clusters.

But spiral galaxies can't last unless they find more gas. Gas is not just a galaxy's means

pirals

The great spiral galaxies that adorn the modern universe are running out of gas and may someday lose their beautiful shapes.

WHIRLPOOL GALAXY: NASA / ESA / S. BECKWITH (STSCI) / HUBBLE HERITAGE TEAM (STSCI / AURA); THIN GALAXY: NASA / ESA / HUBBLE HERITAGE TEAM (STSCI / AURA); SPIRAL DRAWINGS: MIAKIEVY / DIGITALVISION VECTORS / GETTY IMAGES for making new stars; it's also essential for spiral structure. If a star explodes or a dwarf galaxy skirts by, it stirs up the disk. Stars can't dissipate this turbulence, because they're so small they simply dart past one another and never settle into more sedate trajectories. As a result, a disk made solely of stars becomes thick and loses its spiral.

In contrast, gas clouds do dissipate turbulence, because they are large. When they get stirred up, they smack into one another, lose their random motions, and fall back into the disk. So the disk stays thin and the spiral pattern survives. Thus, to preserve its shape and beauty, every spiral galaxy needs gas.

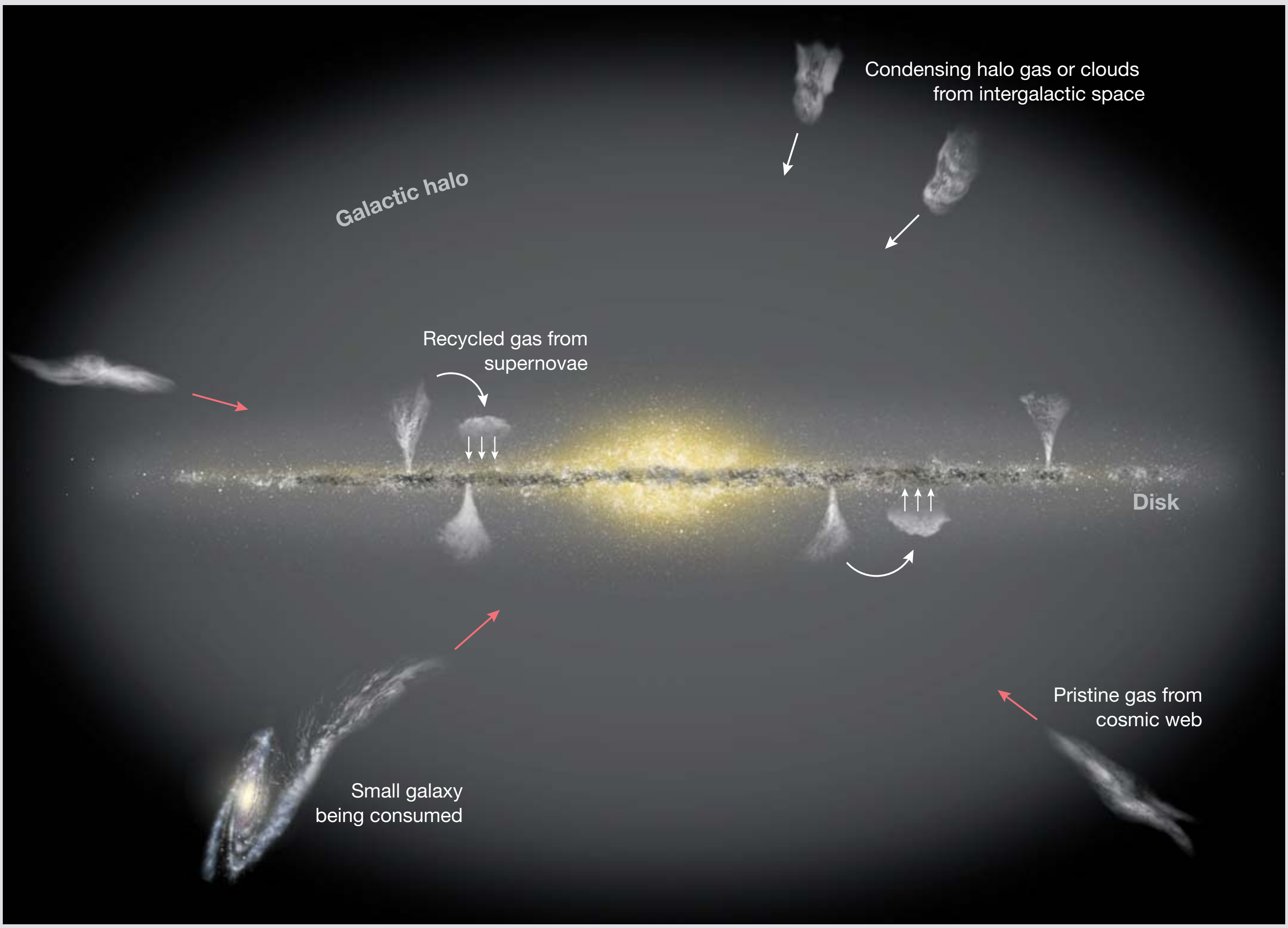
THIN IS IN In terms of diameter to thickness, the Milky Way's thin disk is as slim as a 2-DVD stack.

Running on Empty

For those who hope that the Milky Way's beautiful spiral will endure forever, the numbers on the galactic gas gauge are bleak. "We're simply burning through our fuel too quickly," says Andrew Fox (Space Telescope Science Institute). Stars form primarily in molecular gas, the type that is so cold and dense it can collapse and give birth to new suns. The Milky Way possesses 1 to 2 billion solar masses of molecular gas. Each year our galaxy converts about 2 solar masses of this gas into stars, most of them red dwarfs less massive than the Sun. Divide the molecular gas supply by the star-formation rate and you discover that our galaxy will consume its molecular gas in only about a billion years. Stars do return some gas when they die, but long-lived stars lock up most of it.

Nor is the Milky Way's predicament unique. Other spiral galaxies also face a looming gas shortage. "They'll run out of gas in fairly short times compared to their lifetimes," Fox says. Without gas, the spiral patterns will shrivel. Indeed,

▼ **REFUELING** Giant spiral galaxies such as the Milky Way acquire gas several ways, either from outside themselves (red arrows) or by reusing their own material (white arrows). Some gas comes in pristine form from the cosmic web, some is taken from other galaxies, and some is recycled from the galaxy's own disk. Hot halo gas also condenses, sometimes cooled by recycled gas to form galactic precipitation.



GREGG DINDERMAN / S&T

galaxies known as lenticulars may be deceased spirals. Like spirals, lenticular galaxies have disks, but they possess little gas and have no spiral arms.

Still, spiral galaxies have endured for some 10 billion years. Their success suggests that most have mastered methods to maintain their spiral structure even as they change their gas into stars.

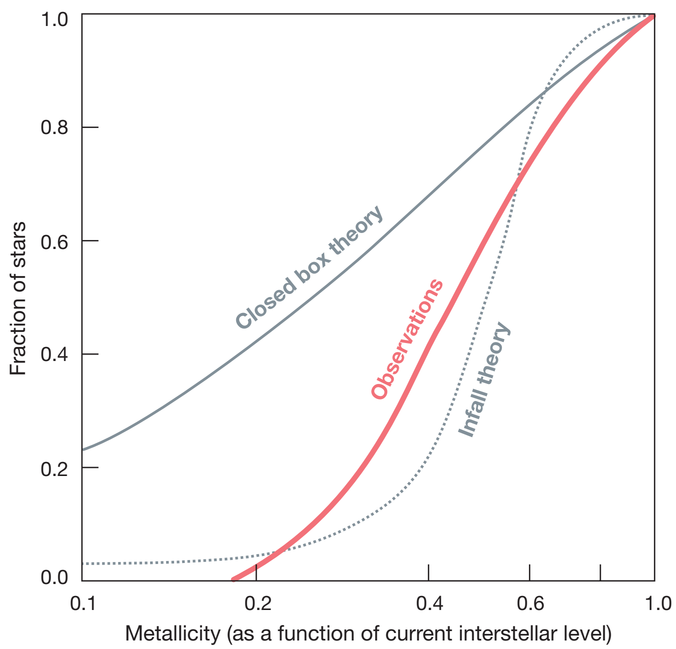
Furthermore, modern simulations of how giant galaxies grow over time predict that gas should rain onto them, replenishing their supply. This gas has three main sources. The first is fairly pristine gas from the cosmic web, the network connecting galaxy groups and clusters throughout the universe. The second is gas from smaller galaxies, which expel it or lose it when straying close to the giants. And the third source of gas comes from the galaxy's own stars, which shed material when they die, sometimes shooting it high above the disk before the gas falls back down.

Long before such simulations existed, astronomers had seen signs that the Milky Way might be acquiring fresh gas. In the early 1960s, radio astronomers spotted high-velocity clouds made of neutral hydrogen; decades later, distance measurements revealed that these clouds reside in our galaxy's halo. In the early 1970s, Richard Larson (Yale University) began contemplating how such clouds would alter the galactic disk if they fell into it. He says, "I immediately realized: Hey, this solves the *G*-dwarf problem."

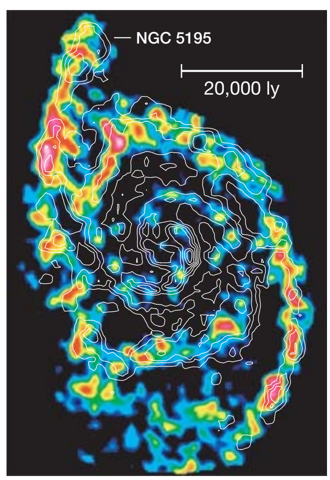
The *G*-dwarf problem describes the distribution of iron levels among long-lived stars, like the Sun, that inhabit the Milky Way's disk. The Sun has a fairly high level of iron, and most disk stars have iron-to-hydrogen ratios similar to the Sun's; iron-poor stars are scarce in the galactic disk. But if the disk had started with vast amounts of iron-poor gas, then lots of iron-poor stars should have arisen before supernova explosions could inject enough iron to enrich all that gas. Furthermore, if the galaxy had never received more gas, the iron levels would just keep going up with time. As a result, disk stars should have a broad range of iron levels, from iron-poor to iron-rich, contrary to observations.

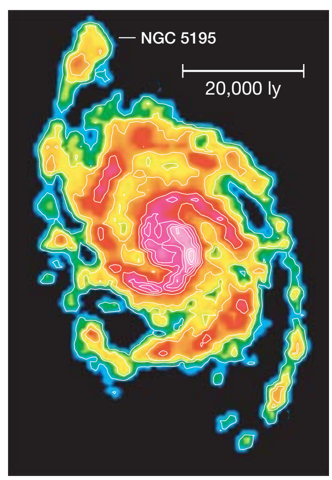
Larson realized that if the disk had actually started out less massive, with just a small amount of iron-poor gas, supernovae would have quickly boosted its iron level, making all later stellar generations iron-rich. Furthermore, if the infall of iron-poor gas balanced the star-formation rate, then the exploding stars would enrich the gas as it fell in so that all stars born from it became about equally iron-rich, agreeing with observations.

Still, astronomers have struggled to see actual signs of gas accreting onto nearby galaxies. In 2016, Yong Zheng, then at Columbia University, and her colleagues detected gas falling onto M33, a spiral galaxy much smaller than our own. By using the Hubble Space Telescope to observe seven hot stars in M33's disk, the researchers discerned triply ionized silicon ions in this gas that were absorbing some of the stars' ultraviolet light, and the Doppler shift of these spectral lines indicated the gas was falling into the galaxy. M33 mints stars at the rate of 0.2 to 0.5 solar masses a year, but the observations indicate that the side of the galaxy facing us accretes about 2.9 solar masses of gas a year. "It's pretty surprising that we find a number that's five to ten times higher," says Zheng. Perhaps gas falls into galaxies sporadically, and this galaxy is currently enjoying a downpour.



▲ **THE *G*-DWARF PROBLEM** Observations in the mid-20th century (red line) revealed that Sun-like stars in the Milky Way's disk all had similar fractions of heavy elements — instead of the wide spread expected if the galaxy existed as a "closed box" that slowly built up its metal content with time (solid gray line). Infalling gas mixed with material in the disk creates stars that better match reality (dotted line).



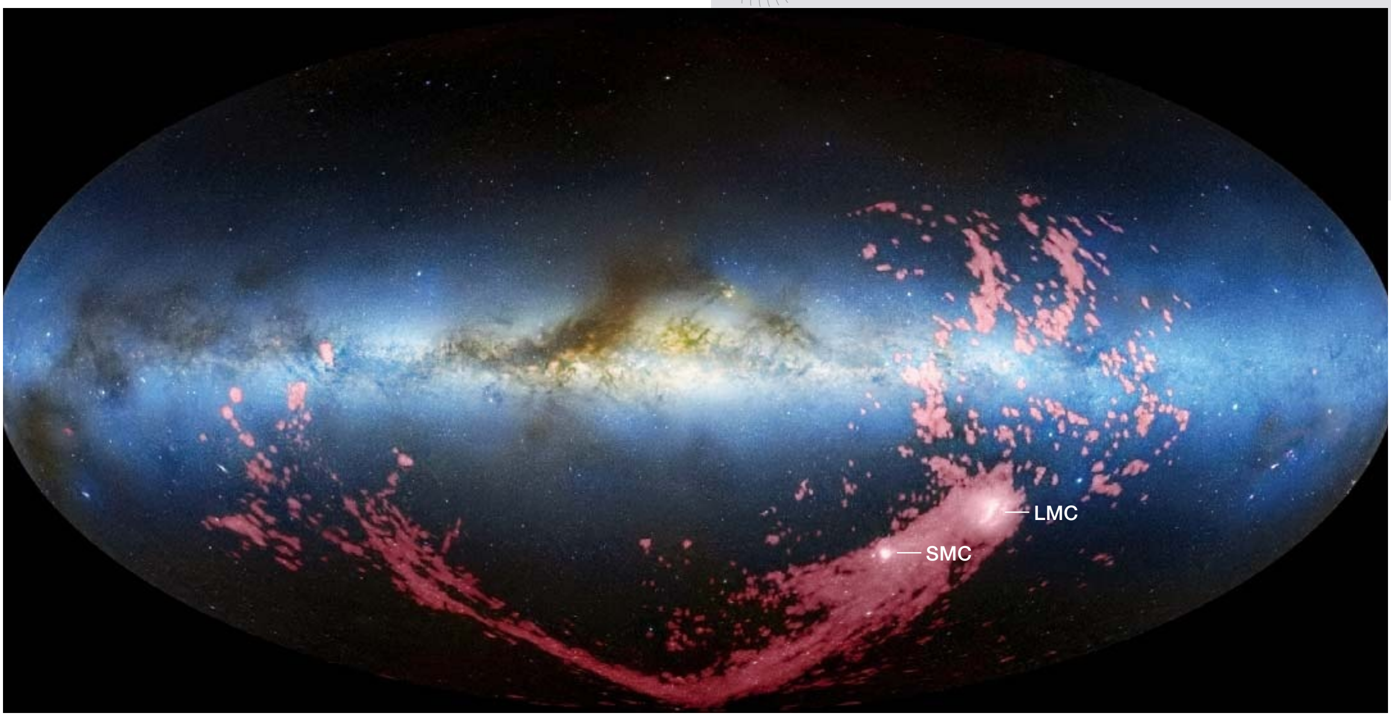


▶ **ATOMIC VS. MOLECULAR** In most spirals, such as the Whirlpool, most of the atomic gas (left) resides on the disk's outskirts, whereas most of the molecular gas (right), the type that forms stars, lies closer to the galaxy's heart. Also included is the Whirlpool's companion galaxy, NGC 5195 (top of both images). Redder colors indicate more gas.

Meanwhile, spiral galaxies possess an additional reservoir of fuel: atomic gas. Made mostly of individual hydrogen and helium atoms, this gas is less dense than the molecular variety and rarely forms stars. The Milky Way has 8 billion solar masses of the stuff; if it can convert this gas into fuel, then the gas will be enough to support its current star-formation rate for another 4 billion years.

"Bringing it in is the problem," Elmegreen says. Whereas most of the molecular gas is closer to the galactic center than we are, most of the atomic gas is more remote, forming a disk that extends far beyond the stellar one in which we reside. But just as a star that skirts by the solar system should gravitationally fling comets from the distant regions toward the Sun, so a passing galaxy should nudge the atomic gas in the Milky Way's outer disk inward, making the gas dense enough

The Milky Way has 8 billion solar masses of atomic gas; if it can convert this gas into fuel, then the gas will be enough to support its current star-formation rate for another 4 billion years.



▲ **HEAVENLY WRECKAGE** This composite radio (pink) and optical image shows the Magellanic Stream, a vast swath of gas stretched out behind the Large and Small Magellanic Clouds (white dots at head of stream). The gas will eventually become part of the Milky Way.

to become molecular and spark new stars. Conveniently, the Andromeda Galaxy will swing by in about 5 billion years, although the latest measurements of its motion suggest it will score less of a direct hit than thought a few years ago. But, Elmegreen says, "it doesn't take much of an interaction to bring that gas in."

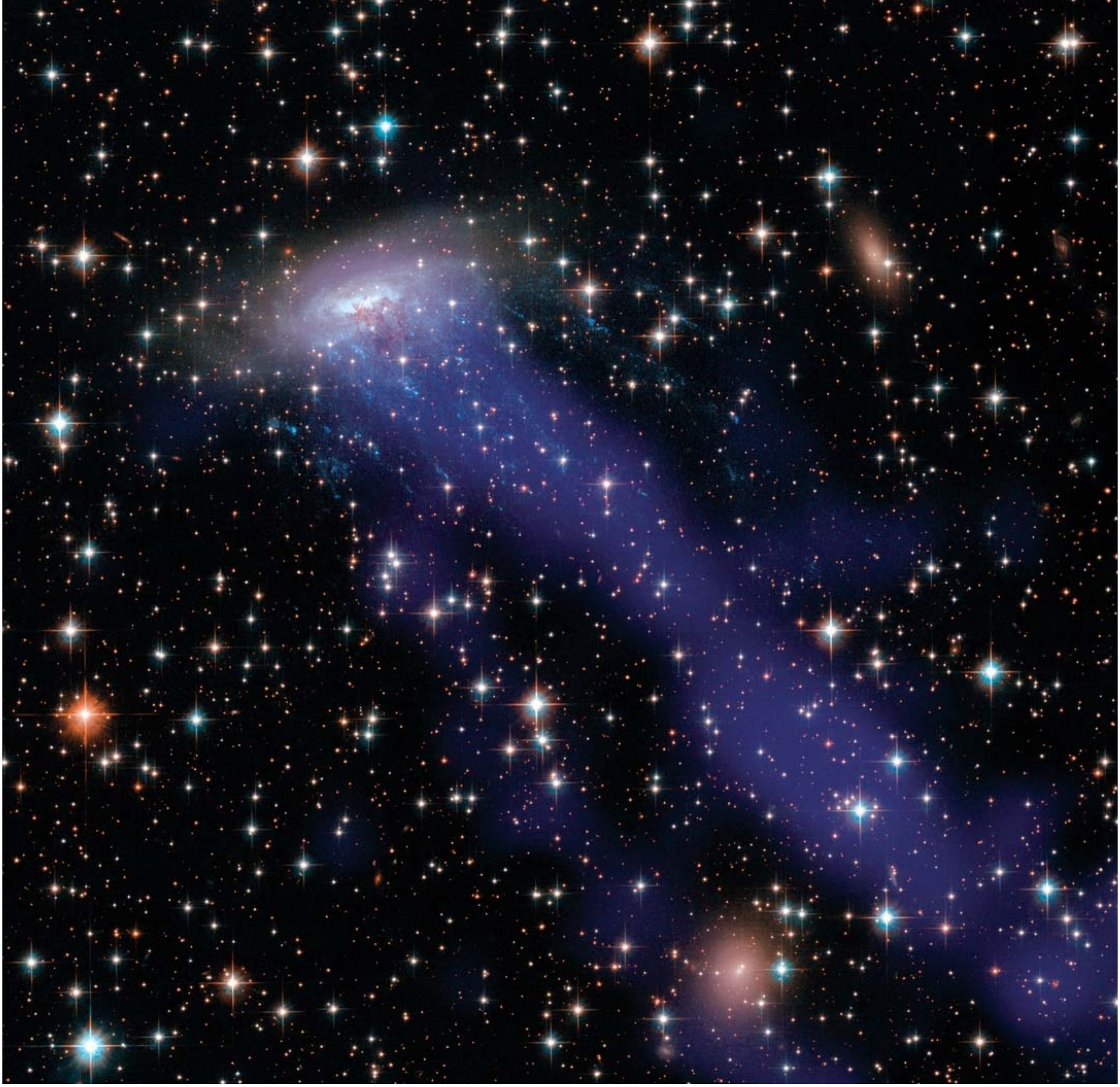
Support Your Local Galaxy

When it comes to future sources of gas, there's more nearby than just an upcoming push from our spiral neighbor in Andromeda. Like other giants, the Milky Way has plenty of lesser galaxies that revolve around it. Most of these satellite galaxies have lost their gas, presumably to our galaxy, which means that stars in other galaxies forged some of the atoms in your body. But unlike most giant spirals, the Milky Way is especially lucky, for it also boasts a pair of satellites that are close, bright, and still full of gas: the Large and Small Magellanic Clouds, 160,000 and 200,000 light-years away.

For billions of years, the Magellanic Clouds have probably been dancing around each other, their gravity tearing out each other's gas. This lost gas now stretches more than half a million light-years through our galaxy's outer halo. The stream could refuel the Milky Way's disk and thereby sustain its spiral.

Moreover, new work has quadrupled the Magellanic Stream's estimated gas mass. Astronomers have long known of the neutral atomic hydrogen gas there, because it emits

MAGELLANIC STREAM: DAVID L. NIDEVER ET AL. / NRAO / AUI / NSF AND MELLINGER / LEIDEN / ARGENTINE / BONN SURVEY, PARKES OBSERVATORY, WESTERBORK OBSERVATORY, AND ARECIBO OBSERVATORY; SPIRAL DRAWINGS: MIAKIEVY / DIGITALVISION VECTORS / GETTY IMAGES



▲ **JELLYFISH GALAXY** This composite X-ray (blue haze) and optical image reveals the hot gas trailing off the spiral galaxy ESO 137-001 as it plows through the Norma Cluster. Bluish newborn stars bedazzle gas tendrils near the disk.

X-RAY: NASA / CXC / UAH / M. SUN ET AL.; OPTICAL: NASA / ESA / HUBBLE HERITAGE TEAM (STSCI / AURA)

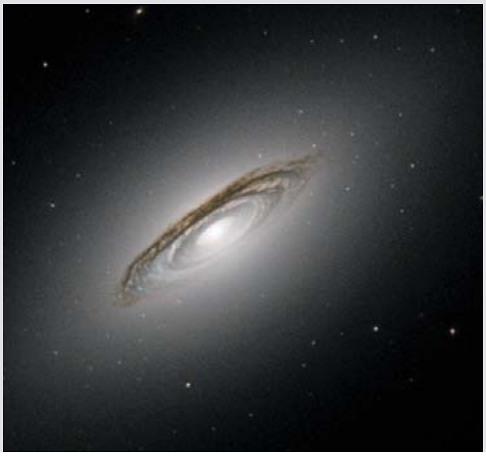
21-centimeter-long radio waves. But in 2014, Fox's team detected large quantities of a different type of gas, gas that is ionized. In such gas, the hydrogen atoms have lost their electrons. This gas emits no radio waves but does absorb ultraviolet light from background quasars. Surprisingly, there's three times more ionized gas than neutral. Altogether the Magellanic gas adds up to some 3 billion solar masses. The amount could even be twice that if, as is likely, much of the Magellanic Stream is more distant than the two galaxies: The farther the gas, the more there must be to explain the strength of the radio waves we detect.

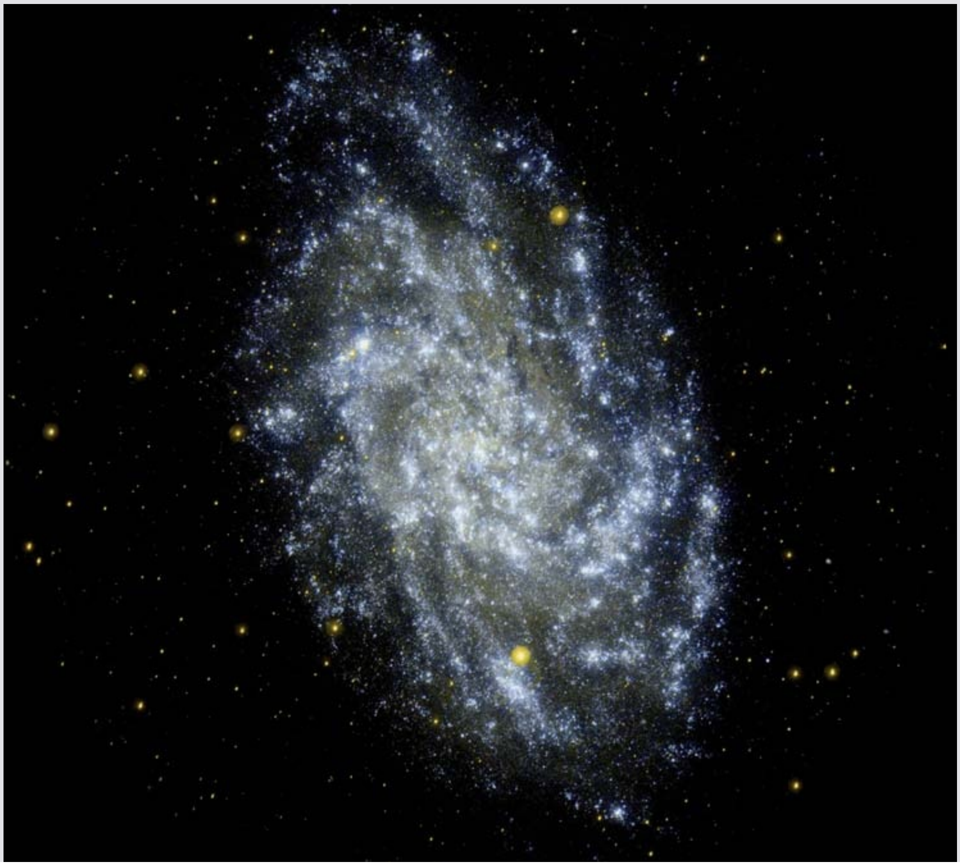
"That helps us out enormously," says F. Jay Lockman (Green Bank Observatory). "It's got a *huge* amount of gas. That has got to fall down eventually. I mean, we'll get that gas."

Fox himself is more cautious, though, because in order to help the Milky Way, that gas must fall into the disk. But the galaxy's halo harbors million-degree gas that, though tenuous, could evaporate the infalling gas before it gets here, just as hot dry air over a desert can cause rain to vanish before reaching the ground.

The hot halo gas itself represents yet another potential source of fuel. Because the halo is vast, spanning more than a million light-years, all that hot, diffuse gas adds up. One recent estimate put the total at 25 billion solar masses, more than twice what's in the disk. Other giant spirals also have hot gaseous halos, which astronomers detect because the gas

No one knows whether the proposed solutions will really supply enough gas to maintain these magnificent galaxies. How much longer will they survive?





▲ **GALAXY LENS** *Left:* NGC 6861 in the constellation Telescopium is a lenticular galaxy: It has the dust lanes common to spirals but a whitish oval shape typical of ellipticals. *Right:* The Andromeda and Milky Way galaxies eclipse in size this third large spiral of the Local Group, the Triangulum Galaxy (M33). This ultraviolet image shows the hot, young stars that trace the galaxy's arms.

emits X-rays and absorbs radiation from background quasars.

Hot, diffuse gas can't make stars, however. Unless this gas cools and sinks into the disks, it will do the spirals no good, in which case they'll resemble thirsty sailors at sea who see water all around them that they can't drink.

The Galactic Fountain

The disks of spiral galaxies also lose gas. Stellar winds and supernova explosions spew gas into the halo. The Milky Way catapults roughly 10 solar masses out of its disk each year. That might not sound like the smartest thing for a gas-guzzling galaxy like ours to do, but the material rains back down onto the disk and brings some halo gas with it, says Filippo Fraternali (University of Groningen, The Netherlands). The ejected gas, though hotter than the Sun's surface, is much cooler than the million-degree halo gas. So the cool gas chills some of the hot, which condenses onto the cool, just as water in warm indoor air condenses onto cold glass windows during winter. According to Fraternali, this process boosts the mass of gas falling back into the disk by 10% to 20%.

"This 10% to 20% is enough," Fraternali says. The infall supplies 1 or 2 solar masses per year of extra gas, he says. "This is exactly the right amount that you need to feed the star formation." As long as a spiral galaxy keeps making stars, he says, its disk should be able to retrieve new gas from the halo.

Twilight for Spirals

Thus, spiral galaxies do have some tricks up their arms. But no one knows whether the proposed solutions will really supply enough gas to maintain these magnificent galaxies. How much longer will they survive? "I think most spiral galaxies will be running out of gas within 2 to 3 billion years," Fox says. "The exception might be a case like the Milky Way. We are fortunate that we have this nearby fuel reserve in our backyard." If most of the Magellanic Stream gas joins the Milky Way's disk, he says, our galaxy could retain its spiral shape for another 5 or 6 billion years, long enough to tide us over until our encounter with Andromeda.

"Someday the Milky Way will form its last star," says Robert Benjamin (University of Wisconsin, Whitewater). "Given all the uncertainties we have in our understanding of galaxy evolution and galaxy environment, we have no firm way of predicting that date." He guesses it could be any time from 5 to 15 billion years from now.

Because spiral galaxies have thrived for so long, Elmegreen suspects that most will manage to acquire enough gas to sus-

LENTICULAR GALAXY: ESA / HUBBLE / NASA; M33: NASA / JPL-CALTECH: SPIRAL DRAWINGS: MIAKIEVY / DIGITALVISION VECTORS / GETTY IMAGES

▲ **BARRED SPIRAL** NGC 1300 in Eridanus is the quintessential barred spiral, its arms attached to a long central bar instead of spiraling all the way to its core. Star-forming regions dot the arms, and a much smaller spiral (some 3,300 light-years wide) appears in the nucleus.

◀ **CELESTIAL SHEEP** NGC 3521 in Leo is a flocculent spiral, so called for the woolly look of its arms. Flocculent spirals are three times as common as the iconic grand-design spirals, such as the Whirlpool.

BARRED SPIRAL: NASA / ESA / HUBBLE HERITAGE TEAM (STSCI / AURA); CELESTIAL SHEEP: ESA / HUBBLE, NASA, S. SMARTT (QUEEN'S UNIVERSITY BELFAST)

tain their shapes until they meet another danger: falling into galaxy clusters, which have hot gas that strips away galactic gas. "There are lots of ways to kill a spiral," he says. The galaxy can metamorphose into a so-called jellyfish, in which starbirth persists in the torn-out gas streamers that trail behind the galaxy. Eventually the galaxy uses up its gas, cannot accrete any more, and ceases to be a spiral. This process may explain why lenticular galaxies proliferate in galaxy clusters. The nearest galaxy cluster, Virgo, may eventually snatch the Milky Way and Andromeda, but long before then the two giant spirals will probably have collided, exhausting their gas in a colossal starburst as they unite into a single giant, elliptical galaxy. Elmegreen calculates that most spiral galaxies will plunge into clusters during the next 16 billion years.

The Sun will then be a mere white dwarf. Perhaps 20 billion years from now astronomers will see spiral galaxies only from afar and marvel at the ancient era when the universe swarmed with such elegant galaxies. For however and whenever it ends, the Spiraliferous Period is certainly splendiferous.

■ **KEN CROSWELL** was born in a spiral galaxy and earned his PhD at Harvard University for studying it. His book about our galaxy, *The Alchemy of the Heavens: Searching for Meaning in the Milky Way*, features interviews with the astronomers who discovered the Milky Way's spiral shape.

CONSTELLATION CLOSE-UP

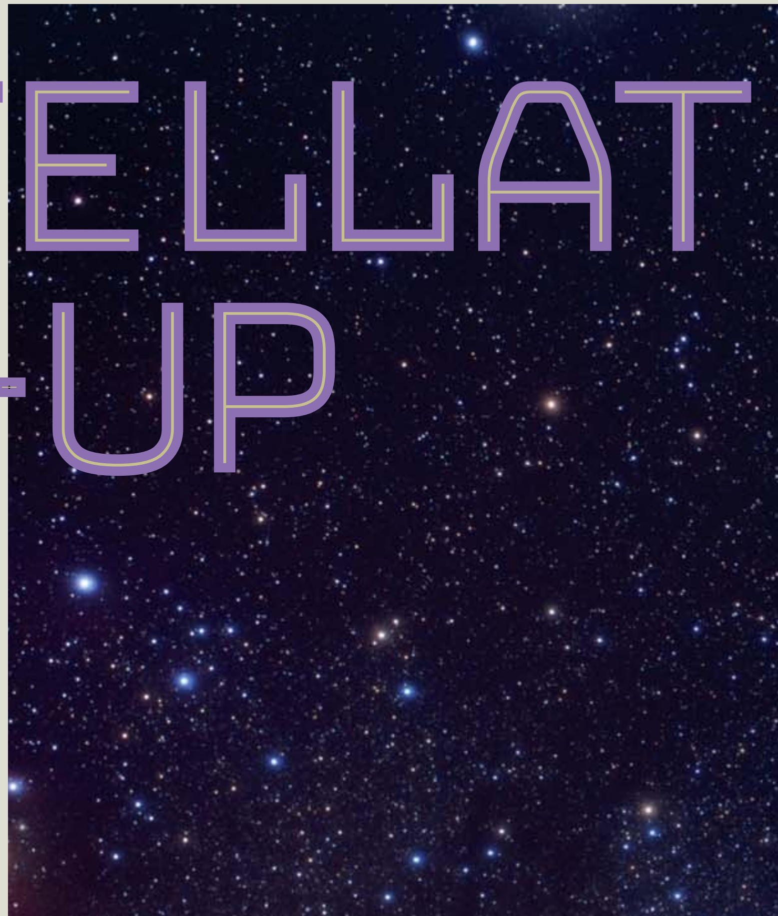
Centaurus and Crux

These far-southern constellations rank near the top in beauty, brightness, and historical interest.

The ancient Greek constellation Centaurus has always held a special place in my imagination. One of the first astronomy facts I ever learned is that **Alpha (α) Centauri**, the constellation's brightest star, is also the closest star to the Sun. But to my great sorrow, I soon found out that I would have to travel at least 800 miles south of my New York City home to see it.

As I learned more, I became increasingly puzzled by that fact. A good chunk of Greece lies north of New York City, and Alpha Centauri is invisible even from Greece's southernmost point. So how did this star become part of one of the ancient Greek constellations?

The answer is that due to precession, the wobble of Earth's axis, Alpha Centauri lay farther north in ancient times than it does now. Earth's North Pole has been tilting away from Centaurus at about ½° per century for the last few millennia, making the constellation ever harder to see from northerly latitudes. Alpha Centauri was still visible from Athens, Greece, during its Golden Age around 450 BC. And as precession pushed the star lower, the center of Greek civilization shifted south, to Alexandria in Egypt.



▶ **CENTAURUS AND CRUX TODAY** Constellation stick figures became popular in the 20th century. They are convenient for quick pattern recognition in light-polluted skies but not always faithful to the traditional story. *Sky & Telescope*'s stick figure puts Centaurus's head where the Greeks visualized his left shoulder.

ION

BRIGHTEST OF THEM ALL
In ancient times Crux, the Southern Cross, marked the rear hooves of Centaurus, the Centaur. That gave Centaurus nine 1st- and 2nd-magnitude stars, two more than runner-up Orion. The prominent white ball just above the line marking the Centaur's back is Omega Centauri, the sky's brightest globular cluster.

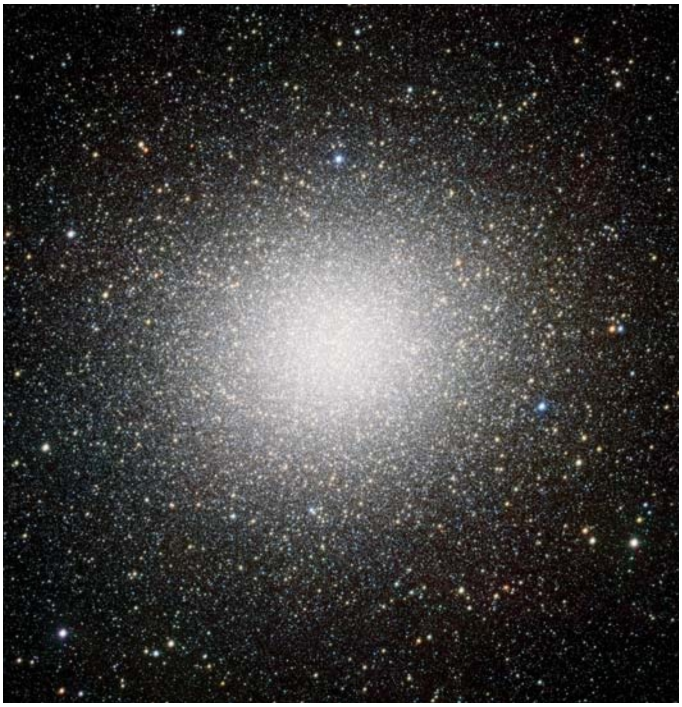
AKIRA FUJII

Moreover, Alpha Centauri is the sky's third-brightest star, so it's prominent even when it's very low in the sky. And it forms a spectacular pair with Beta (β) Centauri, the 11th-brightest.

Immediately west of the Alpha-Beta pair lies another ultrabright star formation, which was dubbed the Southern Cross by 16th-century European navigators and eventually became the modern constellation Crux. But in ancient times those stars, together with Alpha and Beta Centauri, marked the hooves of the Centaur.

This filled me with a great desire to see Centaurus as it appeared when the earliest surviving star catalog was compiled in Alexandria around AD 150 by the great Greek astronomer Claudius Ptolemy. How well does the constellation hang together with and without the Southern Cross? Did it make sense to separate those stars into another constellation?

Fortunately we don't have to guess, because we can counter the effects of precession by the simple expedient of traveling farther south. I fulfilled my dream in April 2018 by flying to Hawai'i, where Centaurus appears almost exactly as it did from Alexandria in Ptolemy's day. But before I discuss that view, let me describe the constellation's appearance from locations more familiar to most *Sky & Telescope* readers.

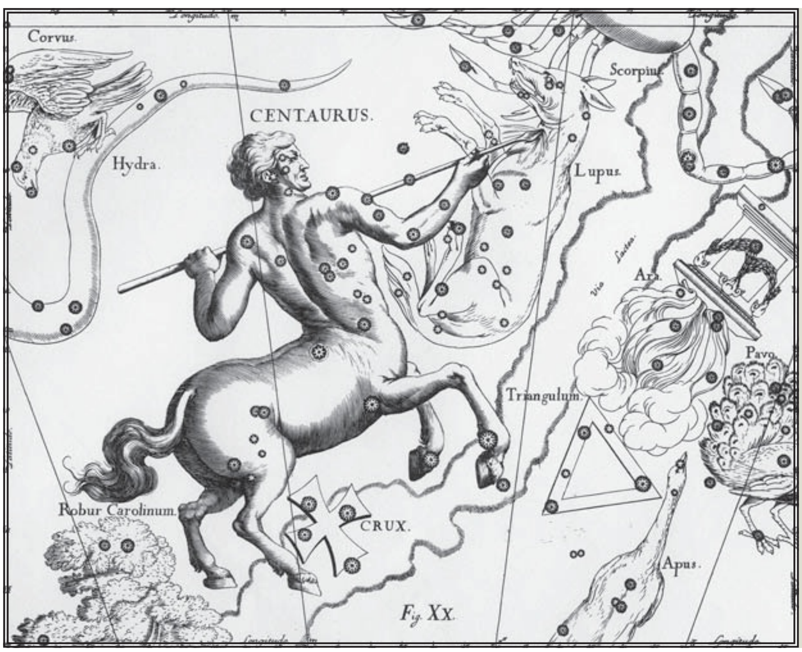


◀ **THE GREATEST GLOBULAR** Omega Centauri, the most massive and luminous known globular star cluster in our galaxy, contains millions of stars. Unlike any normal cluster, its stars span several generations, so it's thought to be the core of a galaxy that was captured and stripped of its outer stars by our galaxy's gravitational field. The same is suspected of several other globular clusters, including 47 Tucanae, Omega Centauri's only rival in brightness and splendor. Sadly, 47 Tucanae lies so far south that it barely skims above the waves even from Hawaii'i's southernmost point.

Head and Shoulders

Centaurus is a big constellation, stretching a long way north-south. So while the Centaur's hooves are invisible from most of North America and all of Europe, its shoulders, marked by Theta (θ) and Iota (ι) Centauri, can be seen throughout the contiguous U.S. and well into Canada and northern Europe. Theta, also known as Menkent, is the brightest star in its sector of sky, and it makes a striking wide pair with Iota, though they're nowhere near as tight nor as bright as the Alpha-Beta pair.

You can compute approximately how far north a southerly star is visible by subtracting its declination from 90°. For instance, Theta and Iota, at declination 36° south, barely



EARLY MODERN CLASSIC

This plate from Johannes Hevelius's *Firmamentum Sobiescianum* (1687–1690) is scrupulously faithful to the descriptions in Claudius Ptolemy's *Almagest*, except that the Centaur's hind legs have been swung back to make room for the Southern Cross. Note that the chart is flipped as compared to what we see from the ground — the night sky is portrayed mirror-reversed, as though painted on the outside of the celestial sphere.

According to ancient Greek tradition, centaurs in general were rude and crude — half human, half horse, and the worst half of both. But Chiron, half-brother to the chief god Zeus, was an exception — wise and pious. After his death he was placed into the sky where he offers Lupus, the Wolf, as a sacrifice on Ara, the celestial Altar. Centaurus and Lupus were probably originally a single constellation; their bright stars are not easy to separate.

OMEGA CENTAURI: ESO / INAF-VST / OMEGACAM / A. GRADO / L. LIMATOLA / INAF-CAPODIMONTE OBSERVATORY; HEVELIUS CHART: JOHANNES HEVELIUS (1690) peek above the horizon from latitude 90° – 36° = 54° north. And from my current home near Boston, Massachusetts, at latitude 42° north, they reach 12° above the horizon when they're highest, which happens around midnight in mid-April or 10 p.m. in mid-May. That makes them easy to spot as long as there aren't any major obstructions to the south.

Under dark skies you should also be able to see the handsome four-star asterism that marks the **Head of Centaurus**. It's halfway between the shoulders and a bit to the north; the stars are numbered 1, 2, 3, and 4 on some charts. If you can't spot the asterism with your unaided eyes, binoculars should show it easily.

Because they're two-dimensional, the stick figures used in modern star charts do a poor job of showing many constellations' traditional figures. The ancient Greeks saw both of the Centaur's shoulders and all four of its hooves clearly, something that's only possible if its torso is twisted as shown at left in a plate from Johannes Hevelius's beautifully engraved 1690 star atlas. Hevelius's stars are very accurately positioned; see how well you can correlate them with the modern chart on page 22 and with the actual stars in the sky, noting that the atlas is flipped. Can you visualize two shoulders and a head in the stars of northern Centaurus?

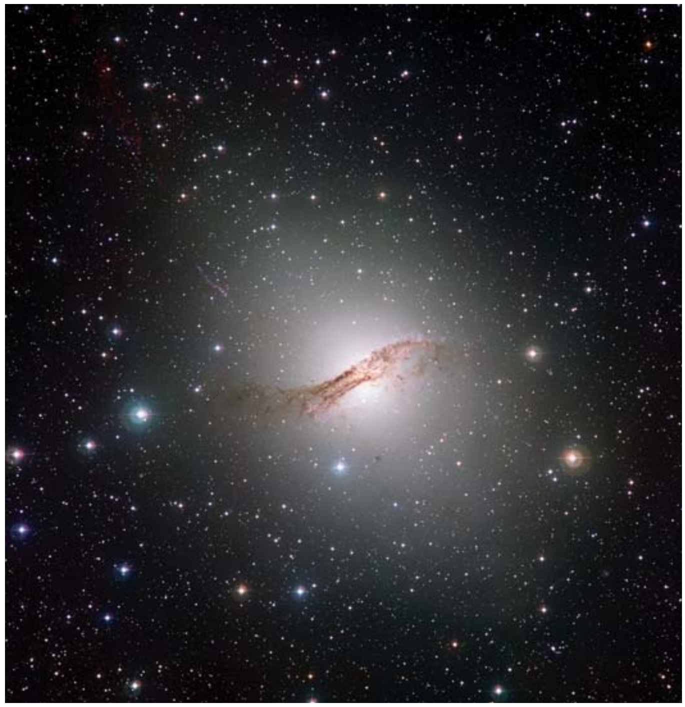
Central Centaurus

The great globular star cluster **Omega Centauri**, also called NGC 5139 and often shortened to Omega Cen, lies near the constellation's center. It's been spotted as far north as Point Pelee in Canada, but you need to be around latitude 35°N or farther south to get a good view. Fortunately that includes much of the United States.

The Omega designation comes from Johann Bayer's 1603 star atlas *Uranometria*, which shows a star with that label at approximately the correct position for the globular cluster. Likewise, the catalog in Ptolemy's *Almagest* includes a star whose position and brightness match the cluster's pretty well. But both works have enough inaccuracies that we cannot say for sure whether these entries were meant to denote the cluster or some faint star near it.

In any case, although Omega Cen is readily visible to the unaided eye in a moderately dark sky, it appears as a circular patch of light, not at all starlike to my eyes. The cluster is amazingly prominent even when it's very low in the sky. It's the most luminous known globular cluster in our galaxy, and also one of the closest — just 17,000 light-years away, compared to 24,000 for the familiar northern globulars M5 and M13. The combination of luminosity and proximity makes Omega Cen appear five or six times brighter than M5 or M13. It's overwhelmingly big and bright through binoculars, and an 8-inch telescope shows countless individual stars. The farther south you can travel, the better it looks.

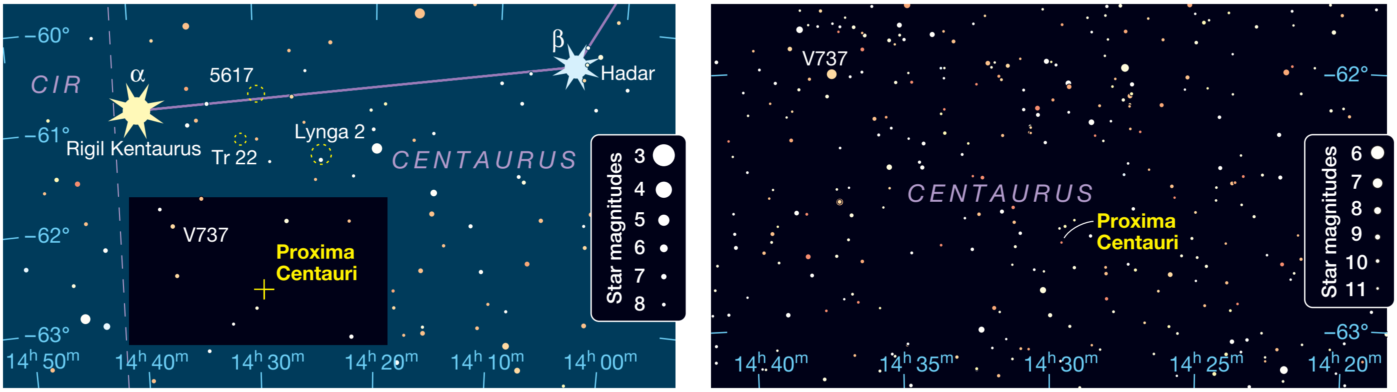
The exotic galaxy **Centaurus A** (NGC 5128) lies 4½° north of Omega Cen. As its name implies, it's the brightest source of radio waves in its constellation. That's due to emissions from its active galactic nucleus — a supermassive black



▲▲ **EXOTIC GALAXY** Centaurus A looks very different from any other galaxy in the sky. It combines the circular outline of a typical elliptical galaxy with a dust lane typical of an edge-on spiral, but much broader and more complex. Although it lies farther north than Omega Centauri, it's harder to observe from northerly latitudes, because atmospheric extinction harms nebulous objects much more than star clusters.

▲ **HOT YOUNG BEAUTY** NGC 4755, the Jewel Box, is very easy to locate 1° southeast of Beta Crucis. It's one of the brightest and most compact open clusters in the sky. All of its brightest stars are short-lived supergiants. This proves that the cluster is exceptionally young, with an estimated age of around 14 million years.

CENTAURUS A: ESO; JEWEL BOX CLUSTER: ESO / Y. BELETSKY



▲ **NEEDLE IN A HAYSTACK** A good chart is essential for identifying faint Proxima Centauri within the densely packed Milky Way star field. There are many cases of stars that appear to be members of a binary pair and are actually chance line-of-sight coincidences. Proxima is a rare example of a star that is known to be gravitationally bound to another but appears to be completely unrelated. In all likelihood such cases are common, but they're hard to detect unless they're extremely close by.

hole that's consuming large quantities of gas and dust. As the material spirals into the black hole, a fraction of it is ejected in high-speed jets, together with copious radiation across the electromagnetic spectrum. Many galaxies contain supermassive black holes, but in mature galaxies they've usually cleared out most of the matter in their immediate vicinity, making them visible only through their gravitational effects.

In many ways Centaurus A resembles a normal elliptical galaxy, but the emissions from its nucleus indicate that it's been stirred up by some recent event, likely a collision with another galaxy. The collision is also presumably responsible for the extraordinary band of dust that encircles Centaurus A's waist. It's by far the easiest dust band to observe aside from the Milky Way's Great Rift, visible through a 6-inch scope from the southern U.S., and showing intricate detail through a large telescope if you travel farther south.

Centaurus A is probably a member of the same group as the spectacular spiral galaxy M83, which lies well to its north. M83 is centered ¼° north of the Hydra/Centaurus border, so if you've ever viewed it through a telescope at low power, you've seen some of Centaurus's stars in the same field of view.

The Glorious Hooves

Presumably the idea that Centaurus is a four-footed animal stemmed from the four brilliant stars near its southern border: Alpha and Beta Centauri, and Alpha and Beta Crucis. These stars are sometimes called Rigil Kentaurus, Hadar, Acrux, and Mimosa, respectively. This is by far the greatest concentration of first-magnitude stars (magnitude 1.49 and brighter) in the entire sky.

When Alpha and Beta Crucis were ripped away to form Crux, the Centaur's hind legs were left either connected to preposterously faint stars, as in the *Sky & Telescope* stick figure on page 22, or dangling in thin air, as shown in Hevelius's atlas. If you swing each hind leg forward to line up with two stars of the Cross, you see the Centaur as the Greeks did — a dynamic figure, with all four legs gathered under it, ready to spring.

On the other hand, there's no question that the Southern Cross is a natural and striking grouping. I see it as a diamond rather than a Cross, since it lacks a star to mark the intersection of the upright and horizontal bars. And Epsilon (ε) Crucis, the fifth-brightest star, fits well into the diamond outline

Targets for Telescopes and Binoculars in Centaurus and Crux

Object	Alias	Type	Distance (l-y)	Mag(v)	Size/Sep	RA	Dec.
Alpha Centauri	Rigil Kentaurus	Double star	4.37	0.0, 1.3	5.2″	$14^h\ 39.6^m$	−60° 50′
Head of Centaurus	1, 2, 3, 4 Centauri	Asterism	—	4.2–4.7	2.7°	$13^h\ 51.8^m$	−33° 00′
NGC 5139	Omega Centauri	Globular cluster	17,000	3.9	55′	$13^h\ 26.8^m$	−47° 29′
NGC 5128	Centaurus A	Galaxy	11,000,000	6.8	26′ × 20′	$13^h\ 25.5^m$	−43° 01′
NGC 4755	Jewel Box	Open cluster	6,400	4.2	10′	$12^h\ 53.7^m$	−60° 22′
Alpha Crucis	Acrux	Triple star	320	1.3, 1.7, 4.8	4.2″, 90″	$12^h\ 26.6^m$	−63° 06′
Proxima Centauri	Alpha Centauri C	Red dwarf star	4.24	11.0	—	$14^h\ 29.7^m$	−62° 41′

Angular sizes and separations are from recent catalogs and papers. Visually, an object's size is often smaller than the cataloged value. Right ascension and declination are for epoch and equinox 2000.0; the right ascensions of Alpha and Proxima Centauri have decreased approximately 0.1^m since then. The separation of Alpha Centauri AB is for epoch 2019.5. The distance given for Centaurus A is a lower limit; the upper limit is around 26,000,000 light-years.

but not into the Cross. But whatever you call it, the formation is shapely, compact, and very bright.

It's too bad that the Southern Cross wasn't recognized as an outstanding asterism yet also left as part of Centaurus, just as the Northern Cross is part of Cygnus and the Big Dipper is part of Ursa Major.

All of Crux and Centaurus are visible from the southern tips of Florida and Texas, though very low in the sky. In some ways that's appropriate, since the Greeks themselves always saw Centaurus hugging the horizon. But traveling even farther south will greatly enhance the view through binoculars and telescopes.

The Milky Way passes through Crux and southern Centaurus, and so the region is swarming with nebulae and open star clusters. The finest of these clusters is **NGC 4755**, also known as the Jewel Box because of the contrast between its red and blue supergiant stars. It's obvious to the unaided eye under dark skies, and breathtaking through optical instruments of all sizes.

Through a telescope at 100×, **Alpha Crucis** and Alpha Centauri are spectacular double stars. The components of Alpha Crucis are very similar in brightness, almost identical in their blue-white color, and separated by 4.2″. There's also an inconspicuous third component 90″ from the bright pair that may or may not be physically related.

Alpha Centauri's fainter star is just ⅓ as bright as the primary, and distinctly redder. And with an orbital period of 79.9 years, the relative positions of Alpha Centauri A and B change perceptibly from one year to the next (see page 34 for more on this intriguing binary star). They're 5.2″ apart in mid-2019, widening to 10.4″ in 2030.

The Alpha Centauri system has a third component, **Proxima Centauri**, which is currently 0.12 light-years closer than the AB pair. According to a 2017 paper in *Astronomy & Astrophysics*, Proxima orbits the AB pair about once every 550,000 years. Proxima lies a whopping 2.2° away from AB in the sky, surely a record among double stars. With traditional doubles, the problem is separating the stars at high power. Finding Proxima, by contrast, requires a substantial star-hop from the main pair; the charts at left will help. Proxima isn't much to look at, a feeble red dwarf shining at magnitude 11.0. But tracking it down was one of the most exciting moments in my entire observing career, because this is truly the closest star to our Sun, the bridge between our immediate neighborhood and the galaxy at large. To add to the thrill, Proxima has a planet that appears to orbit in the "habitable zone," where water can exist in liquid form.

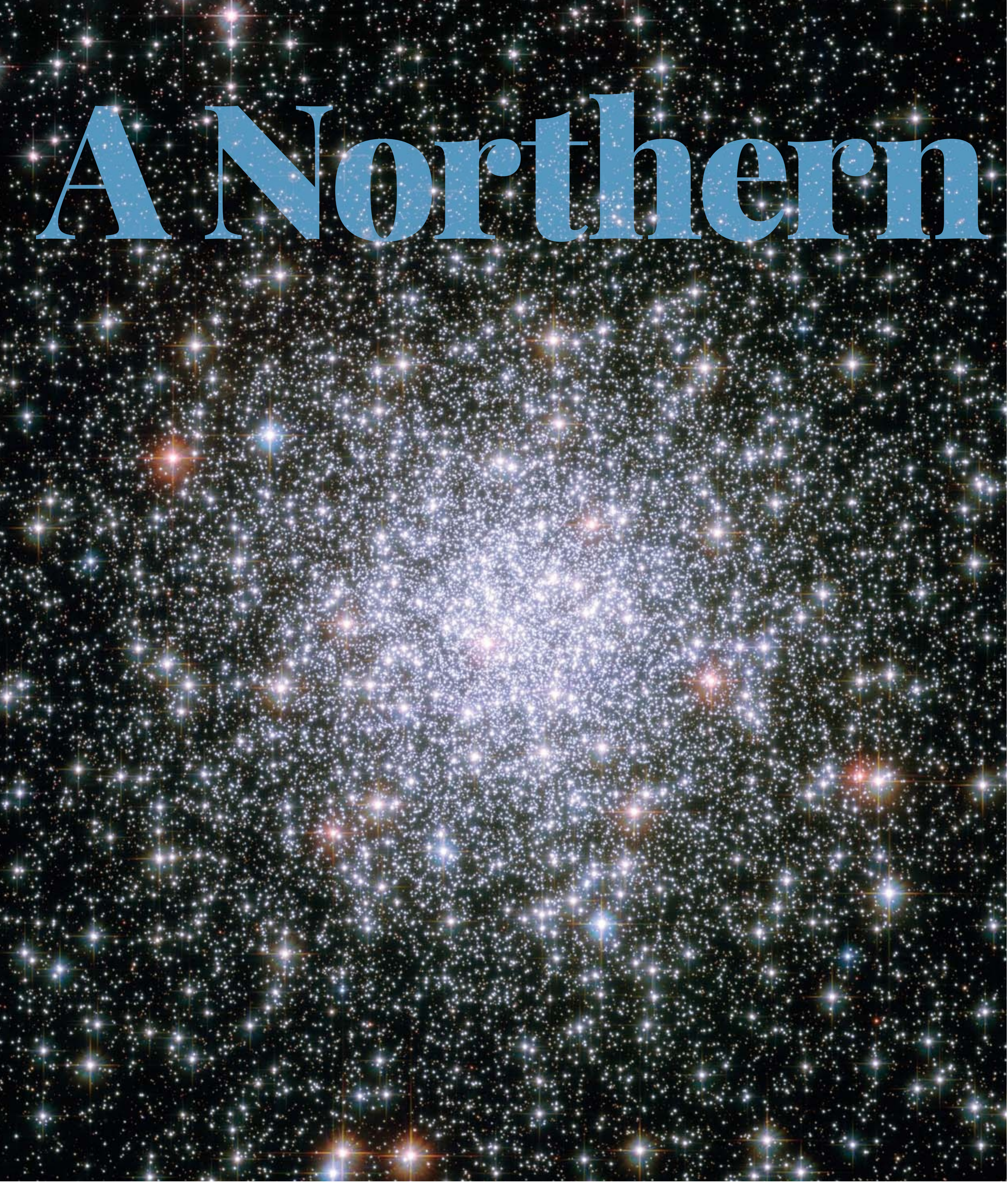
Centaurus and Crux are challenging to observe for most people in mid-northern latitudes. But they are sure to reward your effort because of their great beauty, uniquely significant stars and deep-sky objects, and historical importance.

■ Contributing Editor **TONY FLANDERS** first viewed southern Centaurus from Chile in October 2013, one month before he became an associate editor at *Sky & Telescope*, a position he held until retirement.

LAST CHANCE VIEW
The period the author set aside for astronomy in Hawai'i was plagued by uncharacteristically cloudy weather. His first completely unobstructed view of Centaurus and Crux occurred on the last night of the trip, while camped on a beach on Kaua'i. The Moon was full that night, hiding the faintest stars and reducing the constellations to their simplest form.

TONY FLANDERS

A Northern



Run

Follow these tips to get the most out of a Messier Marathon run from higher latitudes.

A new Moon falls on the night of April 4–5, 2019. This is a perfect date to attempt a Messier Marathon from latitude 49° north (or higher), even though it's considered too late in the year to get the best marathon results from more southerly locations.

Much has been written about Messier Marathons undertaken from the latitude of southern Arizona, for which expert observer Tom Polakis gives the observing window for catching all 110 Messiers as March 20–April 2. As he notes, the northern limit for a full marathon is 40°N, with the optimal latitude around 20°N. But many *S&T* readers live at even higher latitudes, including those of us in the northern tier of the United States, southern Canada, and Europe.

Can you complete the marathon from these locations? On his fifth marathon, well-known supernova hunter Paul Gray scored 109 objects on the night of March 27–28, 2006, from latitude 46.1°N in New Brunswick with his 12.5-inch Dobsonian and 10×70 binoculars. He missed only M30. This is a record for Canada, even though southernmost Ontario is at latitude 42°N. Farther north, the maximum number of Messiers that can be seen in one night decreases steadily.

I've done ten Messier Marathons from a superb site (I drove hundreds of kilometers looking for the best possible treeless western through southeastern horizons) at latitude 49°N on the British Columbia–Washington State border. Now I drive up out of the apricot orchards in bloom to the land of snow at 4,000 feet on a plateau called Anarchist Mountain, east of the Okanagan Valley.

The best score possible from my location is 106 or possibly 107 Messiers in one night, but there are critically important changes in the best observing order for the evening and morning twilight objects from that used in the American Southwest. At this latitude the globulars in far-southern Sagittarius rise much later than they do in Arizona or even in eastern Canada, and, worse yet, they rise on very shallow

ESA / HUBBLE / NASA

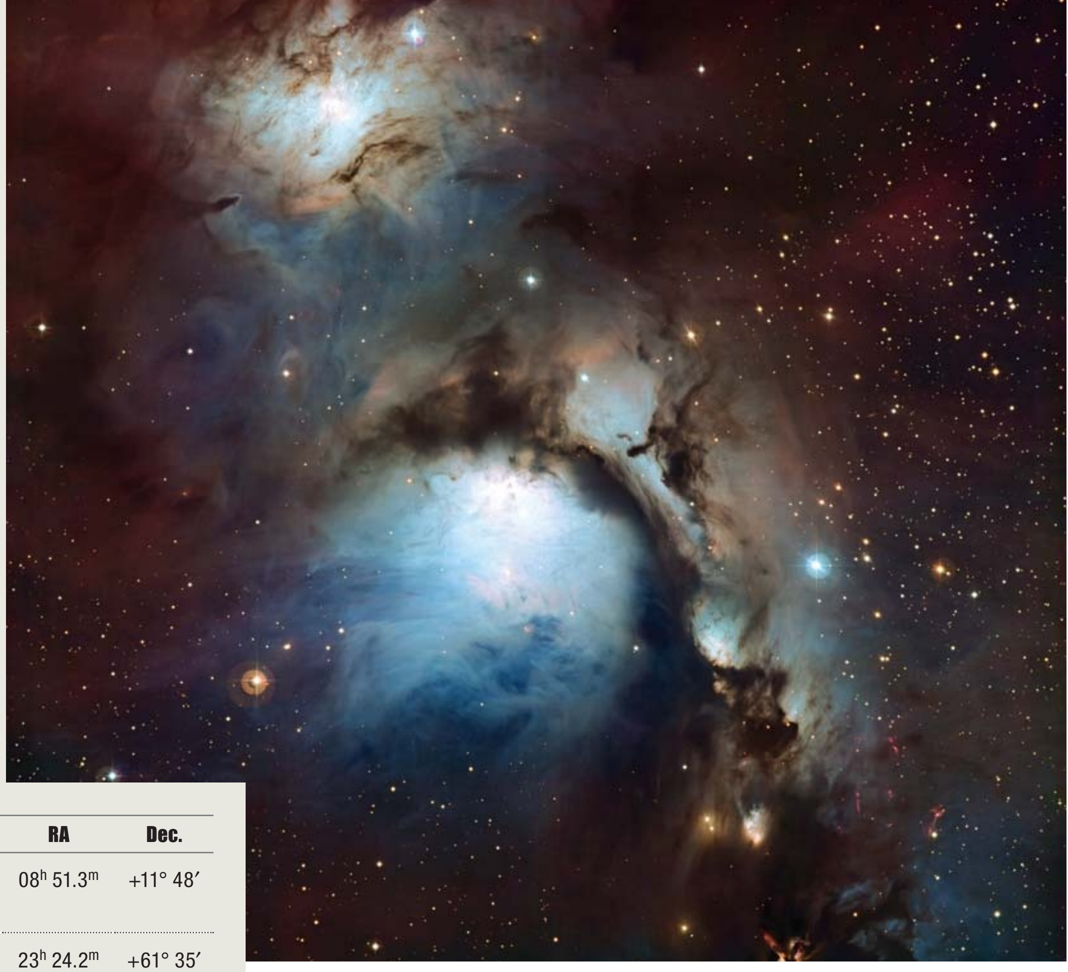
◀ **A BRILLIANT END** If you're observing from more northerly latitudes, the globular cluster M69 in Sagittarius could be the final object of your marathon. You'll be fighting the morning twilight, so look quickly to beat the coming Sun!

A FAR NORTHERN MARATHON

Most Messier Marathon observing lists reflect conditions in southern latitudes. The following tables incorporate the experiences of members of the Okanagan Centre of the Royal Astronomical Society of Canada at latitude 49° north. It also groups binocular objects together.

Object	Constellation	Type	Mag(v)	Size/Sep.	RA	Dec.
M77	Cet	G	8.9	7′ × 6′	02^h 42.7^m	−00° 01′
COMMENT: Invisible by March 30th						
M74	Psc	G	9.4	10′ × 10′	01^h 36.7^m	+15° 47′
COMMENT: Toughest evening object. Invisible by March 25th.						
M79	Lep	GC	7.7	10′	05^h 24.2^m	−24° 31′
COMMENT: Last seen April 2nd, may be visible a few nights longer						
M31	And	G	3.4	178′ × 63′	00^h 42.7^m	+41° 16′
COMMENT: Same field of view as M32, M110						
M32	And	G	8.1	8′ × 6′	00^h 42.7^m	+40° 52′
COMMENT: Same field of view as M31, M110						
M110	And	G	8.5	17′ × 10′	00^h 40.4^m	+41° 41′
COMMENT: Seen through thin cirrus on April 8th.						
M33	Tri	G	5.7	73′ × 45′	01^h 33.9^m	+30° 39′
COMMENT: Binoculars reveal when scopes fail. Requires transparent sky.						
M45	Tau	OC	1.6	110′	03^h 47.0^m	+24° 07′
COMMENT: Naked eye						
M41	CMa	OC	4.5	38′	06^h 46.0^m	−20° 44′
COMMENT: Naked eye or binoculars						
M93	Pup	OC	6.2	22′	07^h 44.6^m	−23° 52′
COMMENT: Binoculars						
M47	Pup	OC	4.4	30′	07^h 36.6^m	−14° 30′
COMMENT: Naked eye or binoculars						
M46	Pup	OC	6.1	27′	07^h 41.8^m	−14° 49′
COMMENT: Binoculars						
M50	Mon	OC	5.9	16′	07^h 02.8^m	−08° 20′
COMMENT: Binoculars						
M42	Ori	EN	4.0	85′ × 60′	05^h 35.4^m	−05° 27′
M43	Ori	EN	9.0	20′ × 15′	05^h 35.6^m	−05° 16′
M78	Ori	RN	8.0	8′ × 6′	05^h 46.7^m	+00° 06′
COMMENT: Requires clear sky						
M1	Tau	SNR	8.4	6′ × 4′	05^h 34.5^m	+22° 01′
M76	Per	PN	10.1	3′ × 2′	01^h 42.4^m	+51° 34′
M103	Cas	OC	7.4	6′	01^h 33.2^m	+60° 42′
M48	Hya	OC	5.8	54′	08^h 13.8^m	−05° 48′
COMMENT: Naked eye or binoculars						
M44	Cnc	OC	3.1	95′	08^h 40.1^m	+19° 59′
COMMENT: Naked eye						

Weather satellite images have shown that to catch the globulars of southern Sagittarius from my site during marathon season, the sky has to be clear all the way to northern Oregon!



▲ **MASQUERADE** Spotting the reflection nebula M78 in Orion will be easier with a transparent sky. While photos reveal a wealth of detail and color, in the eyepiece the nebula resembles a comet with two stars embedded in it.

ESO / IGOR CHEKALIN

A FAR NORTHERN MARATHON (CONTINUED)

Object	Constellation	Type	Mag(v)	Size/Sep.	RA	Dec.
M67	Cnc	OC	6.9	30′	$08^h\ 51.3^m$	+11° 48′
COMMENT: Binoculars						
M52	Cas	OC	6.9	13′	$23^h\ 24.2^m$	+61° 35′
COMMENT: Binoculars						
M34	Per	OC	5.2	35′	$02^h\ 42.0^m$	+42° 47′
COMMENT: Naked eye or binoculars						
M35	Gem	OC	5.1	28′	$06^h\ 08.9^m$	+24° 20′
COMMENT: Naked eye or binoculars						
M37	Aur	OC	5.6	24′	$05^h\ 52.4^m$	+32° 33′
COMMENT: Binoculars						
M36	Aur	OC	6.0	12′	$05^h\ 36.3^m$	+34° 08′
COMMENT: Binoculars						
M38	Aur	OC	6.4	21′	$05^h\ 28.7^m$	+35° 50′
COMMENT: Binoculars						
M3	CVn	GC	6.2	18′	$13^h\ 42.2^m$	+28° 23′
COMMENT: Binoculars						
M81	UMa	G	6.9	21′ × 10′	$09^h\ 55.6^m$	+69° 04′
COMMENT: Same field of view as M82						
M82	UMa	G	8.4	9′ × 4′	$09^h\ 55.8^m$	+69° 41′
COMMENT: Same field of view as M81						
M97	UMa	PN	9.9	3′ × 3′	$11^h\ 14.8^m$	+55° 01′
M108	UMa	G	10.0	8′ × 1′	$11^h\ 11.5^m$	+55° 40′
COMMENT: 49′ northwest of M97						
M109	UMa	G	9.8	7′ × 4′	$11^h\ 57.6^m$	+53° 23′
M40	UMa	—	8.4	0.8′	$12^h\ 22.4^m$	+58° 05′
COMMENT: Double star						

arcs. Consequently, they must be observed at much lower altitudes and in brighter twilight.

So, marathoning at northern latitudes is very challenging. For example, on March 27th (the prime marathon date in southern Arizona) observers at latitude 33°N will find **M70** at an altitude of 19° at the beginning of morning astronomical twilight. On the same morning at my observing site, when M70 finally reaches an altitude of 4°, it's well into twilight, as the Sun is only 15° degrees below the horizon. Weather satellite images have shown that to catch the globulars of southern Sagittarius from my site during marathon season, the sky has to be clear all the way to northern Oregon!

The most difficult evening object is the face-on spiral galaxy **M74** in Pisces. Not only do you have to contend with its low altitude and lingering twilight, but you're hunting in the bright base of the zodiacal light. Expert observer Jim Failes declared M74 invisible at this latitude on March 25th. Here's my cloud-battling experience from 11 days earlier (March 14th), variable cloudiness being typical from this latitude in the spring:

"It was luxurious to have M77 high enough to be an easy catch with my 8-inch Dob. Next I went after M74 with my star atlas and failed on that first 10-minute attempt due to the variable transparency from the cirrus cloud, Venus shining on the cirrus, the bright zodiacal light, and from merely knowing that the galaxy was *somewhere* in the 50× field. I moved off M74 and quickly picked up wonderfully high M33 and M110 so that I didn't have to worry about those two sinking into the murk while hunting too long for M74. Then I dug out a Guide 7 chart of M74's field that I had printed some years ago, with a proven star-hop marked on it with arrows. Thus I knew exactly where amorphous M74 was supposed to be in the field of view. The transparency was varying by about four magnitudes, as shown by nearby Venus. When Venus returned to its full proper brilliancy, and I could see that the sky was apparently clear 6° above right of Venus where M74 lay, I rushed back to M74's field. It took only moments to get there, with Venus as a convenient starting point only a finder field away, and I knew the finder star-hop from a few minutes previously. Almost as soon as I star-hopped to the exact spot with my detailed Guide chart, there was M74, between cirrus patches. Minutes later M74 was clouded out. So it was just a matter of luck in nailing M74, greatly aided by Venus as an indicator of the changing transparency." It was great to start a marathon by getting all the evening objects, but we were clouded out after we got to Hercules.

Guy Mackie, whose sketches have appeared in many *S&T* articles, declared the Seyfert galaxy **M77** invisible by March 30th from my latitude. I use a star chart showing the exact location of M77's relatively bright nucleus, which may shine through cirrus clouds near the horizon if the rest of the

▼ **TAKE A MOMENT** Although he's racing the clock, the author likes to spend extra time with southern objects like M83 in Hydra since he can't see them from his home observing site.

ESO / IDA / DANISH 1.5 M / R. GENDLER / S. GUISARD / C. THÖNE

A FAR NORTHERN MARATHON (CONTINUED)

Object	Constellation	Type	Mag(v)	Size/Sep.	RA	Dec.
M106	CVn	G	8.4	19′ × 8′	$12^h\,19.0^m$	+47° 18′
M94	CVn	G	8.2	7′ × 3′	$12^h\,50.9^m$	+41° 07′
M63	CVn	G	8.6	10′ × 6′	$13^h\,15.8^m$	+42° 02′
M51	CVn	G	8.4	11′ × 7′	$13^h\,29.9^m$	+47° 12′
M101	UMa	G	7.9	22′	$14^h\,03.2^m$	+54° 21′
M102	Dra	G	9.9	5′ × 2′	$15^h\,06.5^m$	+55° 46′
COMMENT: Miserable star-hop at the zenith; could leave until later						
M95	Leo	G	9.7	4′ × 3′	$10^h\,44.0^m$	+11° 42′
COMMENT: Same field of view as M96						
M96	Leo	G	9.2	6′ × 4′	$10^h\,46.8^m$	+11° 49′
COMMENT: Same field of view as M95						
M105	Leo	G	9.3	2′	$10^h\,47.8^m$	+12° 35′
COMMENT: 48′ north of M96						
M65	Leo	G	9.3	8′ × 2′	$11^h\,18.9^m$	+13° 05′
COMMENT: Same field of view as M66						
M66	Leo	G	8.9	8′ × 3′	$11^h\,20.2^m$	+12° 59′
COMMENT: Same field of view as M65						
M104	Vir	G	8.0	9′ × 4′	$12^h\,40.0^m$	–11° 37′
M68	Hya	GC	7.8	11′	$12^h\,39.5^m$	–26° 45′
COMMENT: Need clear sky to the south						
M53	Com	GC	7.7	13′	$13^h\,12.9^m$	+18° 10′
M64	Com	G	8.5	9′ × 5′	$12^h\,56.7^m$	+21° 41′
M60	Vir	G	8.8	7′ × 6′	$12^h\,43.7^m$	+11° 33′
COMMENT: Same field of view as M59						
M59	Vir	G	9.6	5′ × 4′	$12^h\,42.0^m$	+11° 39′
COMMENT: Same field of view as M60						
M58	Vir	G	9.7	6′ × 5′	$12^h\,37.7^m$	+11° 49′
M89	Vir	G	9.8	4′	$12^h\,35.7^m$	+12° 33′
COMMENT: Same field of view as M90						
M90	Vir	G	9.5	10′ × 5′	$12^h\,36.8^m$	+13° 10′
COMMENT: Same field of view as M89						
M91	Com	G	10.2	5′ × 4′	$12^h\,35.4^m$	+14° 30′
M88	Com	G	9.6	7′ × 4′	$12^h\,32.0^m$	+14° 25′
M86	Vir	G	8.9	8′ × 6′	$12^h\,26.2^m$	+12° 57′
COMMENT: Same field of view as M84						
M84	Vir	G	9.1	5′	$12^h\,25.1^m$	+12° 53′
COMMENT: Same field of view as M86						
M87	Vir	G	8.6	7′	$12^h\,30.8^m$	+12° 24′
M99	Com	G	9.9	5′ × 5′	$12^h\,18.8^m$	+14° 25′
M98	Com	G	10.1	10′ × 4′	$12^h\,13.8^m$	+14° 54′
M100	Com	G	9.4	7′ × 6′	$12^h\,22.9^m$	+15° 49′

A FAR NORTHERN MARATHON (CONTINUED)

Object	Constellation	Type	Mag(v)	Size/Sep.	RA	Dec.
M85	Com	G	9.1	7′ × 5′	12^h 25.4^m	+18° 11′
M61	Vir	G	9.7	6′ × 6′	12^h 21.9^m	+04° 28′
M49	Vir	G	8.4	9′ × 8′	12^h 29.8^m	+08° 00′
COMMENT: End of the Virgo Cluster, take a short break						
M83	Hya	G	7.6	11′ × 10′	13^h 37.0^m	−29° 52′
COMMENT: Be ready to observe early if necessary; despite the rush, I spent 10 minutes at high power on this southern splendor that I can't see from my backyard						
M13	Her	GC	5.8	20′	16^h 41.7^m	+36° 28′
COMMENT: Naked eye						
M92	Her	GC	6.5	14′	17^h 17.1^m	+43° 08′
COMMENT: You should have worked your way across the sky to fairly low in the east by about 1 a.m. local daylight time. Take a one-hour nap if you're on schedule.						
M57	Lyr	PN	8.8	1.5′ × 1′	18^h 53.6^m	+33° 02′
M56	Lyr	GC	8.3	9′	19^h 16.6^m	+30° 11′
M29	Cyg	OC	6.6	7′	20^h 23.9^m	+38° 32′
M39	Cyg	OC	4.6	32′	21^h 32.2^m	+48° 26′
COMMENT: Naked eye or binoculars						
M71	Sge	GC	8.2	7′	19^h 53.8^m	+18° 47′
M27	Vul	PN	7.4	8′ × 6′	19^h 59.6^m	+22° 43′
COMMENT: Binoculars						
M5	Ser	GC	5.6	23′	15^h 18.6^m	+02° 05′
COMMENT: Binoculars						
M12	Oph	GC	6.7	16′	16^h 47.2^m	−01° 57′
COMMENT: Binoculars						
M10	Oph	GC	6.6	20′	16^h 57.1^m	−04° 06′
COMMENT: Binoculars						
M107	Oph	GC	7.9	13′	16^h 32.5^m	−13° 03′
M14	Oph	GC	7.6	11′	17^h 37.6^m	−03° 15′
M9	Oph	GC	7.7	12′	17^h 19.2^m	−18° 31′
M4	Sco	GC	5.6	36′	16^h 23.6^m	−26° 32′
COMMENT: Locate en route to M80						
M80	Sco	GC	7.3	10′	16^h 17.0^m	−22° 59′
M19	Oph	GC	6.8	17′	17^h 02.6^m	−26° 16′
M62	Oph	GC	6.5	15′	17^h 01.2^m	−30° 07′
COMMENT: Another southern beauty that I spent 10 minutes with at high power since I can't see it from my backyard						
M11	Sct	OC	5.8	14′	18^h 51.1^m	−06° 16′
M26	Sct	OC	8.0	15′	18^h 45.2^m	−09° 24′
M16	Ser	OC	6.0	7′	18^h 18.8^m	−13° 47′
COMMENT: Binoculars; the 12 objects from M16 to M7 should take less than 10 minutes						
M17	Sgr	EN	6.0	11′	18^h 20.8^m	−16° 11′
COMMENT: Binoculars						

galaxy is hidden by poor transparency. My latest views of M74 and M77 were on a March 19th.

The new Moon of April 4–5 arrives too late in the season to allow for viewing either M74 or M77 from far northern latitudes, but I encourage you to try for them some time in March since they're both such an iconic part of Messier Marathoning.

The third difficult evening object is **M33**. I once succeeded with a detailed star chart showing the exact location of the galaxy's brightest knot, NGC 604! One year, on April 2nd, four of us found that 7×50 binoculars revealed M33 when our Dobsonians could not. While **M31** and **M32** are easy, adjacent **M110** is more amorphous and can't be allowed to get too low. I prefer to use a minute to pick up M31 and its satellites before beginning what can be a long and sometimes fruitless search for M33.

Seeing the globular cluster **M79** isn't considered a problem in Arizona, but its southerly declination means that my last success here at latitude 49°N was on April 2nd when its altitude was 4.2°, with the Sun at an altitude of –14°. M79 might still be visible on April 4th.

> **It's also wise to invest a couple of minutes to pick up the southerly open clusters M41, M93, M47, and M46 with binoculars before they get too low in horizon clouds . . .**

It's also wise to invest a couple of minutes picking up the southerly open clusters **M41**, **M93**, **M47**, and **M46** with binoculars before they get too low in horizon clouds, as unfortunately happened to one of our observers one night when he refused to concede defeat to M33 and move on.

Are there any advantages to higher latitudes? There are only three minor ones. Southern observers make a point of getting **M52**, **M103**, and **M76** early, before they set. But they're circumpolar at this latitude, and one night when variable clouds prevented me from following my intended observing list I eventually picked up M76 when it was at its lowest point, below the pole.

All obstacles considered, if the night of April 4–5 is very transparent with clear skies right down to the western, southern, southeastern, and eastern horizons, the most Messier objects that can be found from latitude 49° north should be 106, possibly even 107, missing M74, M77, and probably M79 in the evening and the impossible **M30** in the morning. If you also miss M33 and **M55** you can still be very pleased with yourself for scoring 104 from so far north. My best result was 105 on April 8–9, 2000, when I missed M33 in thin moonlit cirrus clouds but found M55 at an altitude of only 3.3° with

NASA / ESA / STScI / S. ANDERSON (UNIVERSITY OF WASHINGTON) / J. CHANAMÉ (PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE)

▲ **SOUTHERN STAR CLUSTER** The globular cluster M62 in Ophiuchus is another good place to take a break. Does M62 look slightly brighter in its southeast quadrant? It's one of the closest globulars to the center of the Milky Way, and the distribution of its stars is being affected by galactic tidal forces.

the Sun at –14°. I detected M55 with motion and some resolution at 91× with my 8-inch Newtonian.

From Calgary at 51°N Tom Cameron recorded 104 with a 12-inch reflector on April 1–2, 1995. From the Prince George Astronomical Observatory at 54°N Doug Wayland found 96 on March 16–17, 2002. He enjoyed clear skies due to an Arctic high pressure ridge, but consider this quote: "I found myself having to wait for objects to rise, which was a blessing, as that gave me a chance to warm up. I never got totally warm though and I felt chilled. Fortunately the wind stopped, but –20°C is still very cold even without the wind." Doug missed M74 and M77 in the evening due to trees, and **M6**, **M7**, the Aquarius objects, and the southern Sagittarius globulars in the morning due to his high latitude and an early marathon.

If the weather cooperates this April, how many Messiers will you bag from your latitude?

■ Contributing Editor **ALAN WHITMAN's** bucket list includes doing a Messier Marathon from southern Arizona.

FURTHER READING: Do you want to report your Marathon results, or read reports from previous marathons? Visit **messier.seds.org/xtra/marathon/results.html** for marathon results dating back to 1977. Read Doug Wayland's report of his first Messier Marathon at **astrobuysell.com/paul/wayland.htm.**

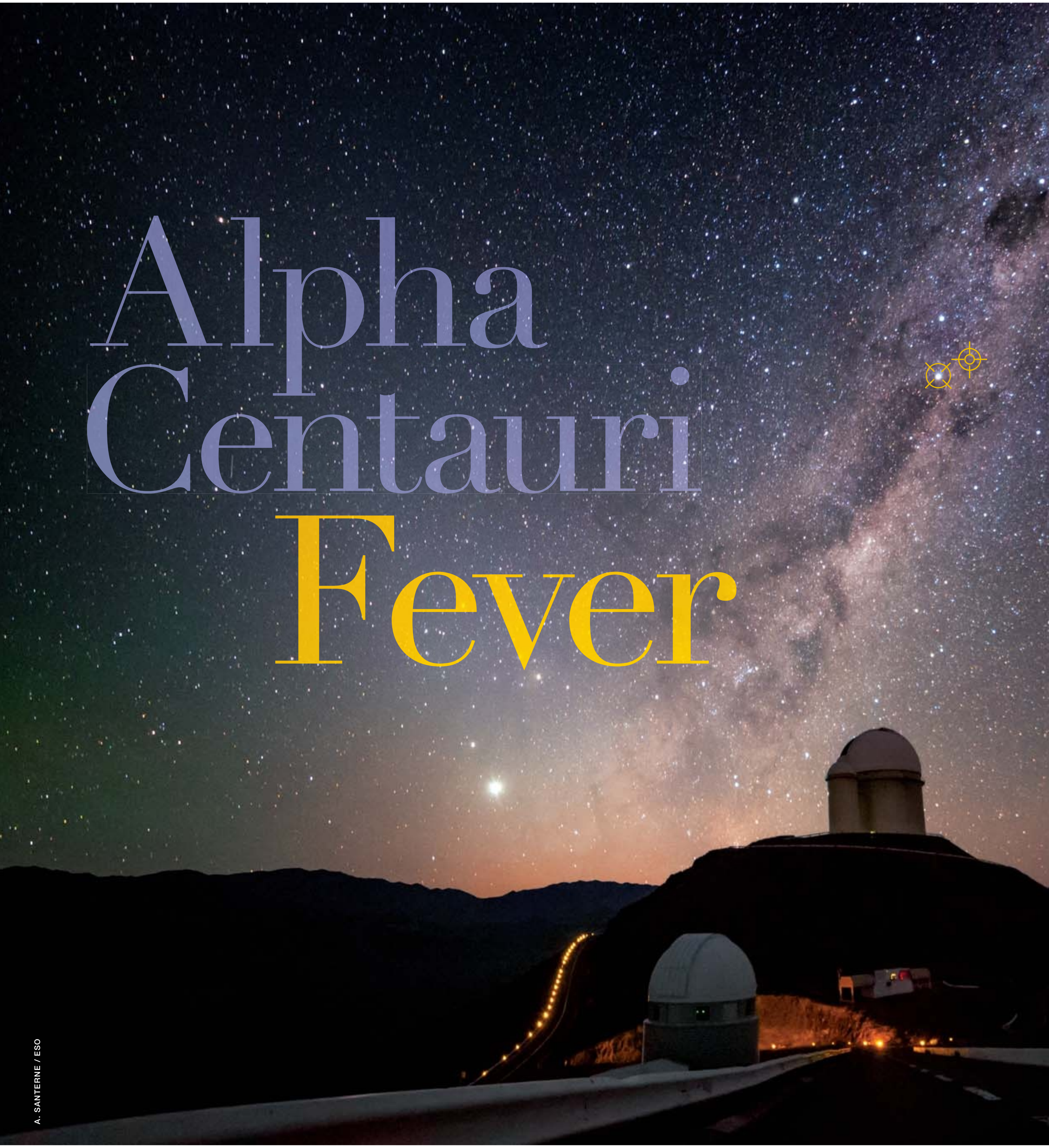
A FAR NORTHERN MARATHON (CONTINUED)

Object	Constellation	Type	Mag(v)	Size/Sep.	RA	Dec.
M18	Sgr	OC	6.9	9′	$18^h\,19.9^m$	–17° 08′
COMMENT: Binoculars						
M24	Sgr	—	4.6	90′	$18^h\,16.9^m$	–18° 29′
COMMENT: Naked eye star cloud						
M23	Sgr	OC	5.5	27′	$17^h\,56.8^m$	–19° 01′
COMMENT: Binoculars						
M25	Sgr	OC	4.6	32′	$18^h\,31.6^m$	–19° 15′
COMMENT: Binoculars						
M22	Sgr	GC	5.1	32′	$18^h\,36.4^m$	–23° 54′
COMMENT: Binoculars						
M8	Sgr	EN	—	90′ × 40′	$18^h\,03.8^m$	–24° 23′
COMMENT: Naked eye or binoculars						
M20	Sgr	EN	6.3	28′	$18^h\,02.6^m$	–23° 02′
COMMENT: Binoculars						
M21	Sgr	OC	5.9	13′	$18^h\,04.6^m$	–22° 30′
COMMENT: Binoculars						
M6	Sco	OC	4.2	25′	$17^h\,40.1^m$	–32° 13′
COMMENT: Naked eye or binoculars						
M7	Sco	OC	3.3	80′	$17^h\,53.9^m$	–34° 49′
COMMENT: Naked eye or binoculars just as it rises						
M28	Sgr	GC	6.8	11.2′	$18^h\,24.5^m$	–24° 52′
COMMENT: Probably needs a scope						
M15	Peg	GC	6.2	18′	$21^h\,30.0^m$	+12° 10′
M2	Aqr	GC	6.5	16′	$21^h\,33.5^m$	–00° 49′
COMMENT: Morning twilight rush; on April 5th at latitude 49°N, astronomical twilight begins at 4:37 a.m. daylight-saving time at the central meridian for your time zone						
M73	Aqr	—	9.0	3′	$20^h\,58.9^m$	–12° 38′
COMMENT: Asterism; star-hop to M72 from here						
M72	Aqr	GC	9.3	7′	$20^h\,53.5^m$	–12° 32′
COMMENT: More difficult than M73						
M75	Sgr	GC	8.6	7′	$20^h\,06.1^m$	–21° 55′
M54	Sgr	GC	7.7	12′	$18^h\,55.1^m$	–30° 29′
M70	Sgr	GC	7.9	8′	$18^h\,43.2^m$	–32° 18′
COMMENT: Don't confuse with NGC 6652, which lies between M69 and M70						
M69	Sgr	GC	7.7	10′	$18^h\,31.4^m$	–32° 21′
M55	Sgr	GC	6.3	19′	$19^h\,40.0^m$	–30° 58′
COMMENT: Very tough on April 5th						
M30	Cap	GC	7.2	12′	$21^h\,40.4^m$	–23° 11′
COMMENT: Not visible						

G = galaxy; GC = globular cluster; OC = open cluster; EN = emission nebula; RN = reflection nebula; PN = planetary nebula; SNR = supernova remnant. 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.

 by Javier Barbuzano

Alpha Centauri Fever



A. SANTERNE / ESO

The allure of the closest star system to ours infects astronomers and venture capitalists alike.

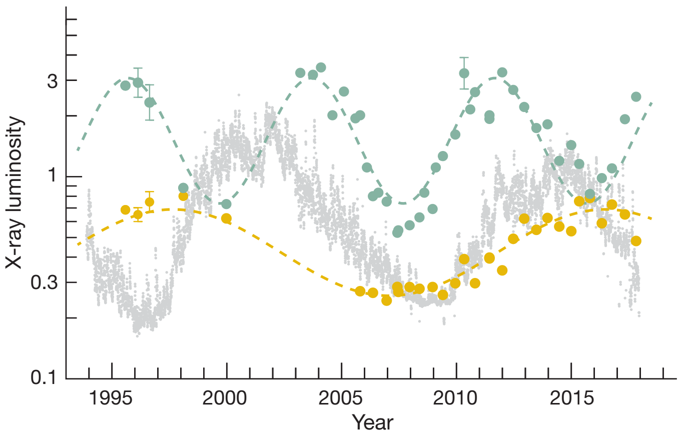
In 1831, an outbreak of scarlet fever at the Cape of Good Hope killed the director of the Royal Observatory. Thomas Henderson, a promising Scottish astronomer, was asked to come and replace him. Henderson was understandably hesitant to leave the safety of his home in Edinburgh for the dangers of the remote British colony, but he ultimately decided it would be good for his career and took the job.

Henderson arrived in March 1832 at what he described as a "dismal swamp" and quickly started mapping the posi-

The Alpha Centauri binary forms the third brightest star in the entire sky, only surpassed by Sirius and Canopus.

tions of hundreds of southern stars. In his 13-month stay (he resigned after a request for additional funding was denied) he made a series of measurements that would grant him a place in the pantheon of astronomy. These were precise recordings of the position of Alpha Centauri, a binary that forms the third brightest star in the entire sky, only surpassed by Sirius and Canopus. He later used the observations to measure the binary's *parallax*, the apparent shift in its position in the sky caused by Earth's yearly motion around the Sun (*S&T:* Mar. 2019, p. 26). The parallax revealed that this bright double star was the closest stellar neighbor to the solar system.

◀ **THE CENTAUR'S HOOF** The Alpha Centauri system hovers above La Silla Observatory in northern Chile.



▲ **CYCLIC BEHAVIOR** X-ray observations of Alpha Cen A and B show that B has a regular, roughly 8-year activity cycle (green), similar to the Sun's 11-year cycle (gray). The star A (yellow) might have a 19-year cycle, or the drop in the late 2000s could have been an anomaly similar to the Sun's Maunder Minimum between 1645 and 1715.

We now know that Alpha Centauri is actually a *triple* system (probably), and that at least one exoplanet orbits its smallest stellar member. Only about 4.3 light-years away from us, the triplet's proximity — and the possibility of studying its planets — has captured the imagination of scientists, astronomy buffs, and at least one Silicon Valley mogul who is willing to invest part of his fortune to fund its exploration.

Meet the Neighbors

It was Jesuit missionary Jean Richaud who discovered that Alpha Centauri is a binary. In 1689 he was observing a comet from Pondicherry in India when he realized that the star could be split into two using a small telescope. "The two stars . . . seemed to be practically touching each other," he wrote.

The binary comprises two Sun-like stars orbiting each other in close quarters, Alpha Centauri A and B, which together are the brightest star in the southern constellation of Centaurus. The pair is particularly interesting for astrophysicists, since both stars are similar to our Sun. Alpha Centauri A is 10% more massive and 50% brighter than the Sun and of a similar spectral type, which means it's a yellow star with a surface temperature of nearly 6000K. B is smaller and dimmer, an orange *K* dwarf that's 10% less massive and half as bright as our star. In a way, they're like alternate scenarios of the Sun, if it had just had slightly different properties.

Both stars are older than the Sun, with an age of roughly 6 billion years. They circle each other every 80 years, with a close approach of 11.3 astronomical units and a maximum separation of 35.7 a.u. For comparison, if A were our Sun, B's orbit would swing from just beyond Saturn to a bit farther than Neptune.

Being so close to Earth, the pair can teach astronomers more in less observing time than other stars can. "It makes observing programs a lot easier to get approved," says Tom Ayres (University of Colorado, Boulder), who has studied Alpha Centauri since the 1970s. In 2005 Ayres started using NASA's Chandra X-ray Observatory to monitor Alpha Centauri while trying to explain a sudden drop of X-ray emission from A detected by the European Space Agency's space telescope XMM-Newton. "It just disappeared from view," Ayres says. "It was completely unprecedented."

Sun-like stars produce X-rays in their coronas, their outermost atmospheres, where magnetic fields interact with material superheated to millions of degrees. Looking at these X-rays, astronomers can probe the inner workings of stars, revealing how they evolve with age.

Chandra obtained a complete spectrum of both Alpha Centauri A and B in 2007, which looked strikingly different than data captured in 1999. A's coronal temperature had dropped from more than 2 million degrees, typical of Sun-like stars, to under 1 million degrees, only emitting in the less energetic wavelengths of the X-ray spectrum. The change indicated that the star was going through a magnetic minimum similar to the solar magnetic cycle. "This is exactly what happens on the Sun," Ayres says. "At solar minimum you just have this kind of fuzz."

Since then, Ayres has continued to request Chandra observations of Alpha Centauri every six months or so. His persistence has revealed a "beautiful eight-year cycle" for B's magnetic activity, a bit shorter than the solar 11-year cycle. B typically emits more energetic X-ray radiation than the Sun, too, which might make things less hospitable for life on nearby planets.

Things aren't as clear-cut for Alpha Centauri A. "From 2005 to 2010 the X-rays were very flat, and we don't know whether that's just a natural part of a long cycle or if that is a sort of a mini–Maunder Minimum," says Ayres, referring to a 70-year period of extremely low magnetic activity on the Sun when very few sunspots were observed (*S&T:* Jan. 2018, p. 18). "We don't have enough observations of the Sun or of other stars to have really any experience in these things," he adds.

A Triple System?

More than 200 years after Richaud split AB in his scope, Robert Innes, studying photographic plates at the Union Observatory in South Africa in 1915, found that a

NOT JUST A CENTAUR

For the aboriginal Maoris of New Zealand, Alpha Centauri pairs with Beta Centauri to make the anchor line connecting the great canoe of the Milky Way and its bright stars to its anchor, the Southern Cross. The Inca saw Alpha and Beta Cen as the eyes of the nursing mother llama, which with its baby composes the most important Inca constellation.

S&T ILLUSTRATION, SOURCE: TOM AYRES

dim, 11th-magnitude star lying some 2° from Alpha Centauri had the same proper motion as the binary star across the sky. Shortly after, Dutch astronomer Joan Voûte calculated this star's parallax and distance, showing that it was moving in the same direction and at the same speed as Alpha Centauri and was equally close to Earth. This was the first indication that the three stars formed a triple system.

This star, Alpha Centauri C, is actually the closest star to the Sun. It's a red dwarf with 0.12 solar mass, describing a 550,000-year orbit around AB at a distance of 13,000 a.u., or one-fifth of a light-year. Currently it's on the Earth-side of its orbit, placing it closer to us than AB and earning it its common name: Proxima Centauri.

Historically, astronomers have questioned if Proxima is really orbiting Alpha Centauri or is just a passerby. In 2017, Pierre Kervella (Paris Observatory, France) and others provided the first solid evidence of the trio's gravitational bond by measuring Proxima's speed relative to AB.

The team used the planet-hunting instrument HARPS, installed on the 3.6-meter telescope at La Silla Observatory in Chile. HARPS depends on the Doppler effect to gauge the radial velocity of stars — their speeds towards or away from Earth — to reveal the gravitational tug that orbiting planets exert on them. But what HARPS ultimately does is precisely measure stellar movements recorded in a star's light. Kervella used these measurements to calculate Proxima's velocity relative to Alpha Centauri rather than its movement relative to Earth. "This is much more difficult to measure because the spectrum of Proxima, which is used to measure the Doppler effect, is full of molecular lines all mixed together, which makes it impossible to measure an absolute radial velocity," Kervella says.

Kervella and his colleagues worked around this problem by measuring the radial velocity of Proxima's extended atmosphere, a layer of hot gas that surrounds the star. With this approach, they showed that Proxima's velocity relative to AB is below the system's escape velocity by a significant factor.

But that doesn't mean that Proxima has always been part of the Alpha Centauri system. It could have formed along with A and B from the same primeval cloud of gas and dust, or, maybe, it formed elsewhere and was later captured by the binary star.

Double and triple stars are common in the universe. Perhaps half of all known Sun-like stars have companions, although astronomers aren't quite sure why. Recent research suggests that all stars may be born in orbiting pairs from dense, egg-shaped cores found within cosmic gas clouds. Around 60% of them move farther apart until they eventually split up, while the rest shrink their orbits instead to form tight binaries.

Most researchers think that Alpha Centauri and Proxima formed together. "These kinds of hierarchical triple systems or multiple systems are really quite common," Ayres says. One example, he points out, is the Capella system, made of four stars in two binaries (two Sun-like, two red dwarfs), separated by 10,000 a.u. "It's just the way the stars form, the smaller stuff gets thrown in wider orbits."

But Proxima could have been captured by the binary after a close encounter, says Fabo Feng (University of Hertfordshire, UK). Feng has created simulations that account for the gravitational influence of the Milky Way and close encounters with other stars, which show that the system's current configuration might be unstable for its age. That points to a capture scenario for Proxima.

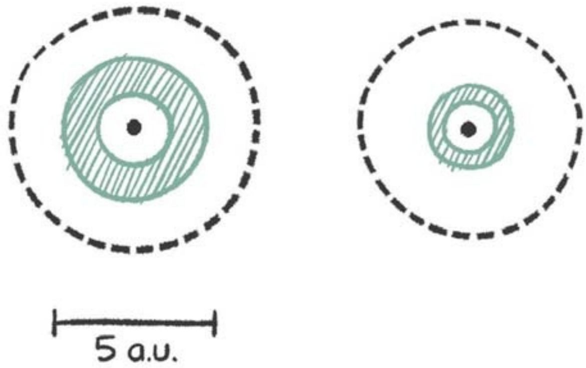
Kervella thinks that if Proxima was captured, it had to be very soon after the three stars formed in close quarters. Otherwise their relative speeds would have been too high to allow the capture. "It's very difficult for an old system to capture a passing star," Kervella says. "This is why we think they might have formed at the same time from the same cluster."

▶ OUR STELLAR CAST In our three-part series we discuss Polaris, the Alpha Centauri system, and Betelgeuse. These stars span a range of sizes, shown to scale. Listed diameters ("D") are approximate and given as multiples of the Sun's diameter. We've included the Sun here for visual reference.

TERRI DUBÉ / *S&T*

Most researchers think that Alpha Centauri and Proxima formed together. But Proxima could have been captured by the binary after a close encounter.

Planet hunters aren't hopeful of finding life-sustaining conditions on any worlds around Proxima, but they have brighter prospects for Alpha Centauri A and B, which are more like our Sun — as long as observers can find planets there, that is.



▲ **STAY BETWEEN THE LINES** Despite being so close together, both Alpha Cen A and B have regions of stability (inside the dotted lines) where planets could safely orbit. Green bands mark the habitable zones.

Looking for Planets

Learning more about the interactions of Alpha Centauri's stars could reveal how probable planets are in the system and how their habitability might have evolved over time. Astronomers have already found one planet orbiting Proxima, using HARPS. Found in 2016, Proxima Centauri b has at least 1.3 Earth masses, is probably rocky, and sits very close to Proxima, around 10% of Mercury's distance from the Sun. It completes an orbit every 11 days (*S&T:* Dec. 2016, p. 10).

Proxima Cen b is within Proxima's temperate zone, where in theory liquid surface water could exist. (The team avoids the more optimistic term "habitable zone.") But red dwarfs such as Proxima frequently release waves of energetic particles that could sterilize the surface of a planet and erode its atmosphere, a process similar to what we think might have happened on Mars (*S&T:* July 2018, p. 14).

Proxima Cen b is so close to its star that it's probably tidally locked, with the same side always facing the incoming radiation. That means that while the star-side of the planet gets toasted, the farside remains cold, unless some convection mechanism (perhaps large-scale mixing in the atmosphere) redistributes part of the heat.

"In a planet around an *M* dwarf that somehow had retained a thick atmosphere or maybe an ocean, life could survive," Ayres says. But he quickly points out that this life would have to evolve to withstand the high levels of radiation, too.

In short, planet hunters aren't hopeful of finding life-sustaining conditions on any worlds around Proxima. But they have brighter prospects for Alpha Centauri A and B, which are more like our Sun — as long as observers can find planets there, that is.

20%
Fraction of known exoplanets that orbit stars in multiple systems

Double- and triple-star systems have certain particularities when it comes to forming and keeping planets. When stars form, most of the available material ends up in the stars themselves. The leftovers form protoplanetary disks where planets could grow. But when two stars form in close quarters, they might disrupt each other's planet-forming disks.

Planets are possible, though; there are several safe zones in binary systems. Each star can harbor its own planet population, depending on how close the stars are to each other. There could also be circumbinary planets orbiting both stars. In fact, about 20% of all known exoplanets are in binary systems. One example is the case of HD 196885 AB, a binary similar to Alpha Centauri AB with a planet orbiting the primary star.

Recent analyses have determined that the stability zones around Alpha Centauri A and B extend to 2 or 3 a.u. from each star, roughly the distance between the Sun and the main asteroid belt. These stability regions also happen to

STABILITY REGIONS: LEAH TISCIONE / *S&T*, SOURCE: T. W. A. MÜLLER AND N. HAGHIGHIPOUR / *ASTROPHYSICAL JOURNAL* 2014, HTTP://ASTRO.TWAM.INFO/HZ/; SYSTEM DIAGRAM: LEAH TISCIONE / *S&T*

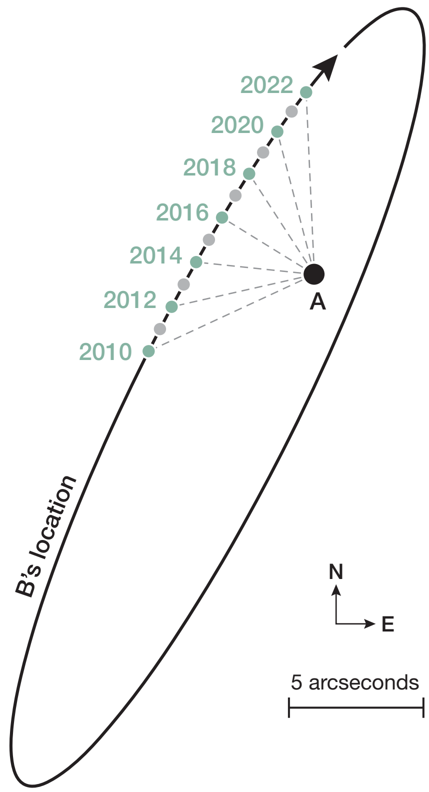
SHIRTTAIL RELATION Proxima Cen lies some 400 times farther from Alpha Cen AB than the stars A and B lie from each other. The distances here are to scale, but the star sizes are not.

cover the habitable zones for both stars. “Those distances around both Alpha Centauri A and B are safe for planets, so if they are there, they would survive,” says Debra Fischer (Yale University), who has led an intensive search for planets around both A and B.

As seen from Earth, Alpha Centauri A and B had a close approach in 2016 and are now slowly moving apart. This prevents effective planet searches using the radial velocity method. “The light from one star will bleed in as we try to take the spectrum of the other star, and that has led to contamination that amplified our errors and made it harder to get the precision we need,” Fischer says.

While waiting for the stars to separate, Fischer and her graduate student, Lily Zhao, have focused their efforts on determining how big a planet could be hiding in the glare. Using observations from HARPS and two other instruments, they have shown that in their habitable zones, Alpha Cen B could harbor one or more unseen mini-Neptunes, and Alpha Cen A could hide a world three times Neptune’s mass. Any gas giants like Saturn would have been already detected with existing instruments.

Alpha Centauri could also harbor circumbinary planets: There is a stable zone beyond 80 a.u. from the binary’s center of gravity. However, being so far from the stars, these planets would be cold, dark, and hard to find.



▲ **INCHING APART** Alpha Cen A and B are moving apart again from our perspective, offering astronomers the opportunity to use the latest exoplanet-hunting instruments to scrutinize the system for alien worlds.

S&T ILLUSTRATION, SOURCE: L. ZHAO ET AL. / *ASTRONOMICAL JOURNAL* 2018

Are We There Yet?

During 2019, Alpha Centauri A and B will move apart enough to resume radial velocity planet searches. When they do, the Echelle Spectrograph for Rocky Exoplanets and Stable Spectroscopic Observations (ESPRESSO), a new instrument 10 times more accurate than HARPS, will be ready at the European Southern Observatory’s Very Large Telescope in Chile. ESPRESSO can measure planet-induced wobbles in a star down to 10 centimeters per second, enough to detect Earth-mass planets in the habitable zone of Sun-mass stars. “I think in the next three to five years we will have an answer,” Fischer says.

In anticipation of a discovery, a private consortium of researchers and institutions is working to design, build, and launch a small space telescope that could take images of planets in the habitable zones of Alpha Centauri A and B. They call it Project Blue, after Carl Sagan’s famous “pale blue dot” moniker for Earth.

According to Jon Morse, Project Blue’s Mission Executive, a small telescope specially designed and packed with all the necessary technology could be built and put in orbit for less than $50 million, a fraction of the cost of a mid-size space mission such as Kepler or Dawn. Such an endeavor would also go against the prevailing philosophy of planet-hunting missions, which now tend to rely on large surveys in order to maximize the chances of finding planets.

“The possibility that there is a no result, that there are no planets that we are able to see, is real,” says Morse. “But we are saying, let’s look to Alpha Cen A and B, it’s the closest Sun-like star by a factor of 2.5, and the optical system you need is much smaller and less expensive.”

Even before seeing blue dots around Alpha Centauri, another initiative is already making plans to send probes there. In April 2016, Silicon Valley billionaire and venture capitalist Yuri Milner created the Breakthrough Starshot

> **"If we shoot to where we think Proxima will be in 50 years, we will miss it by several astronomical units," Kervella says.**

▲ **INTERSTELLAR TRAVELERS** Researchers are working to design a flock of small probes that, accelerated by a laser flash hitting their sails, could reach the Alpha Centauri system in 20 years.

project, a research and engineering initiative that he endowed with $100 million. Its goal is to create a proof-of-concept design for light-propelled nanocraft, tiny space probes accelerated by a giant laser on Earth that could reach Alpha Centauri in a human lifetime. These probes will have a small light-sail that the laser's photons will slam into, accelerating the craft up to a fifth of the speed of light so that it can reach the Alpha Centauri system in 20 years. From there, they will take pictures and send them back to Earth.

The idea sounds simple enough, but there are countless technological and scientific hurdles. Engineers will need to develop the right materials to build the sails, and then miniaturize sensors, antennas, navigation systems, and power sources for the probes. A laser such as the one needed to accelerate them has never been built.

Once en route, other scientific unknowns could easily doom the mission, such as impacts with cosmic dust particles, potentially devastating at high speeds (*S&T:* Dec. 2016, p. 11). We don't even know for sure where the target will be in 20 years to aim the probes, Kervella points out.

THE PLANET THAT WASN'T

Astronomers haven't found planets around either Alpha Cen A or B, but not for lack of trying. In 2012, Xavier Dumusque (then at Geneva Observatory, Switzerland) and colleagues announced that they had found a weak signal in B's light that looked like the wiggle in position induced by an orbiting planet. But others determined that the signal was instead an artifact introduced by the way the team processed their data.

"At the moment we don't have the accuracy for that: If we shoot to where we think Proxima will be in 50 years, we will miss it by several astronomical units," Kervella says.

If habitable planets are found in Alpha Centauri, there's no doubt that humans will eventually want to go there. But would that ever be feasible? If sending a tiny probe is already sci-fi, dispatching a craft large enough to hold a crew could be impossible. Then add the difficulties of keeping humans alive and sane during the long interstellar journey. Even if the trip could be done at half the speed of light, it would take 8 years, significantly longer than the elusive trip to Mars that's still beyond our current technological capabilities.

As formidable as the challenge is, sending people to the lunar surface also seemed highly unlikely only 70 years ago. But once the goal was set, it was achieved in less than a decade. Will humankind have the same resolve when it comes to crossing the interstellar abyss?

■ Former *S&T* intern **JAVIER BARBUZANO** is a freelance journalist based in Barcelona. He's been sending colonists to Alpha Centauri in *Civilization* games for as long as he can remember.

PROBES: LEAH TISCIONE / *S&T*

OBSERVING
April 2019

2 DAWN: Waxing gibbous Venus rises in the east shortly before the waning crescent Moon. The two are less than 5° apart.

8 EVENING: The waxing crescent Moon, Aldebaran, Mars, and the Pleiades form a diamond in Taurus.

9 EVENING: The Moon has leapfrogged over Aldebaran and now sits some 5° above the Bull's brightest star.

10 EVENING: Algol shines at minimum brightness for roughly two hours centered at 8:49 p.m. PDT (11:49 p.m. EDT); see page 49.

11 EVENING: Mars approaches Aldebaran and will be less than 7° from the red giant for the next seven nights. Compare the two red orbs: The star is twice as bright as the planet.

13 EVENING: The waxing gibbous Moon, in Cancer, is but 2° from the Beehive Cluster (M44).

14 EVENING: The fattening Moon visits Leo and is about 5° from the Lion's brightest star, Regulus.

22 MORNING AND EVENING: The Lyrid meteor shower peaks during the evening of the 22nd. Best viewing is during the pre-dawn hours that day, but the waning gibbous Moon, three days past full, will interfere.

22 MORNING: The Moon, by the claws of Scorpius, is some 7° from reddish Antares.

23 NIGHT: The thinning Moon, retrograde Jupiter, and 51 Ophiuchus form a tight triangle from when they rise shortly before midnight to sunup.

25 MORNING: The Moon and Saturn are some 3° apart in Sagittarius for viewers in North America. For those in Eastern Australia, New Zealand, and western South America, the Moon will occult the ringed planet on the morning of the 26th.

— DIANA HANNIKAINEN

▲ Messier 64 is nicknamed the "Black Eye Galaxy" due to the dark band of absorbing dust obscuring the nucleus (see page 58 for a sketch of this galaxy and its surroundings). M64's unusual appearance is thought to arise from the merger of two galaxies long ago.

NASA / HUBBLE HERITAGE TEAM / STSCI / AURA / SCIENCE SOURCE

Lunar Almanac
Northern Hemisphere Sky Chart

Yellow dots indicate which part of the Moon's limb is tipped the most toward Earth by libration.
NASA / LRO

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				

NEW MOON
April 5
08:50 UT

FIRST QUARTER
April 12
19:06 UT

FULL MOON
April 19
11:12 UT

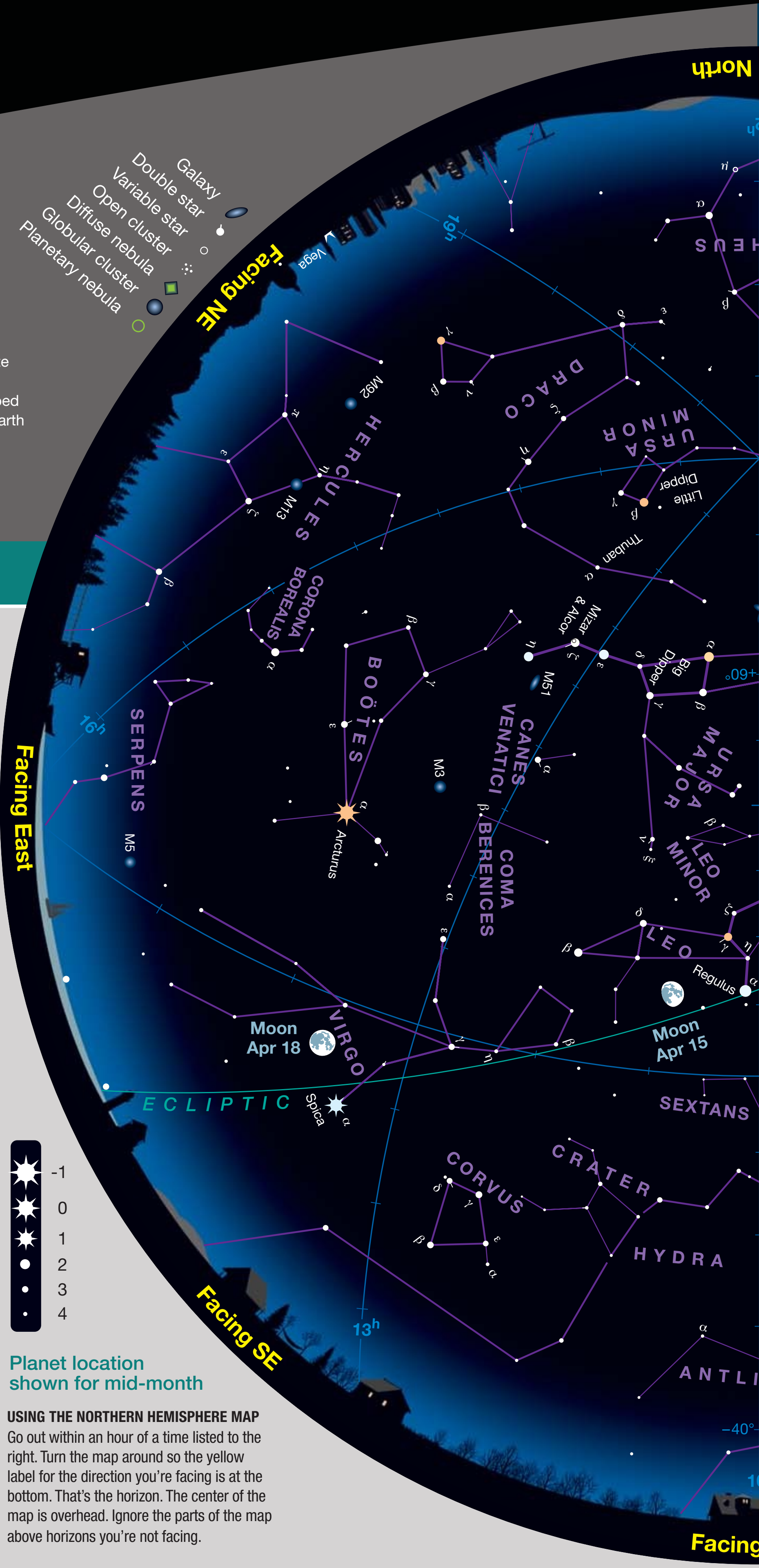
LAST QUARTER
April 26
22:18 UT

DISTANCES

Apogee	April 1, 00^h UT
405,577 km	Diameter 29′ 28″
Perigee	April 16, 22^h UT
364,205 km	Diameter 32′ 49″
Apogee	April 28, 18^h UT
404,582 km	Diameter 29′ 32″

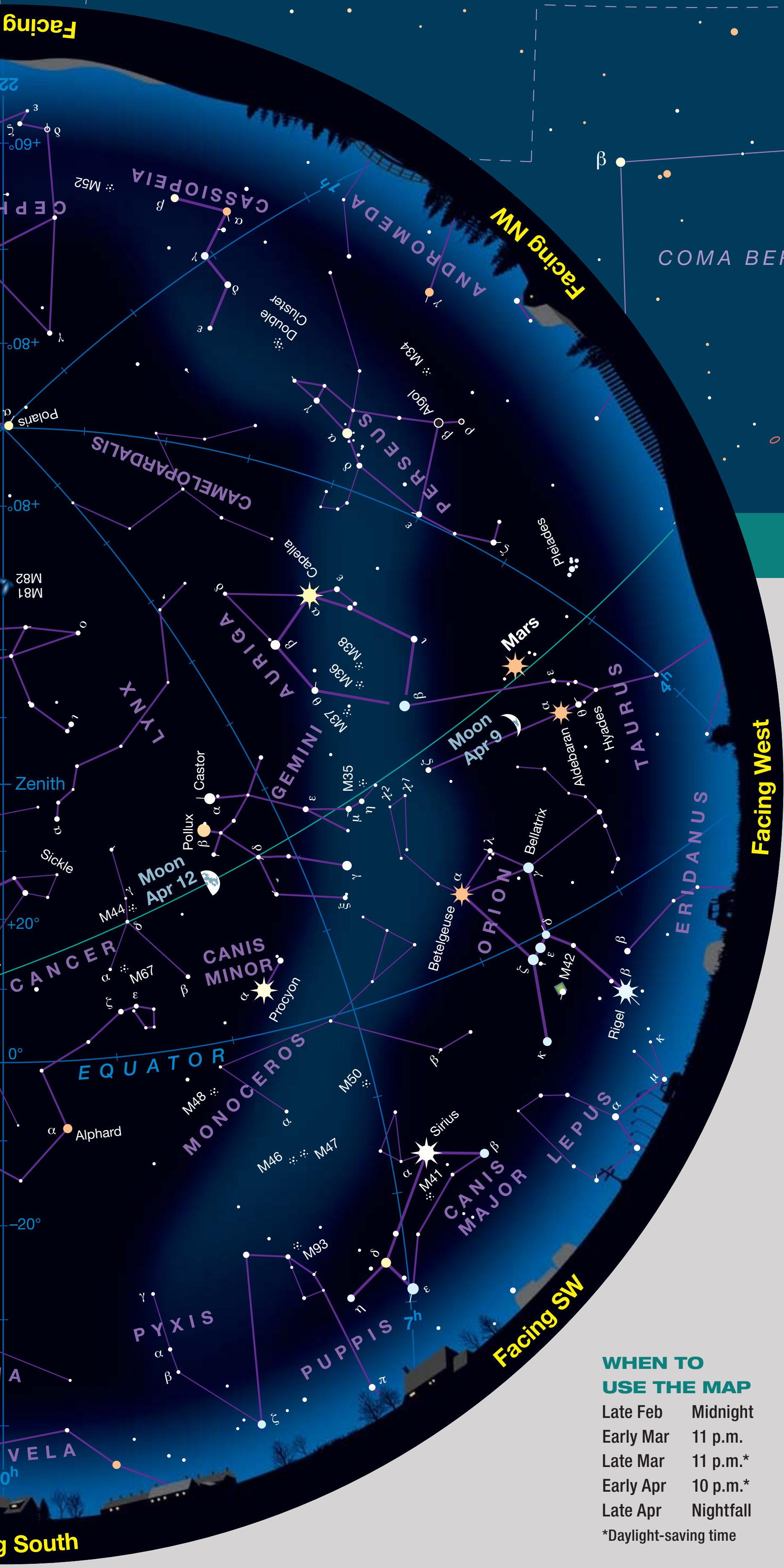
FAVORABLE LIBRATIONS

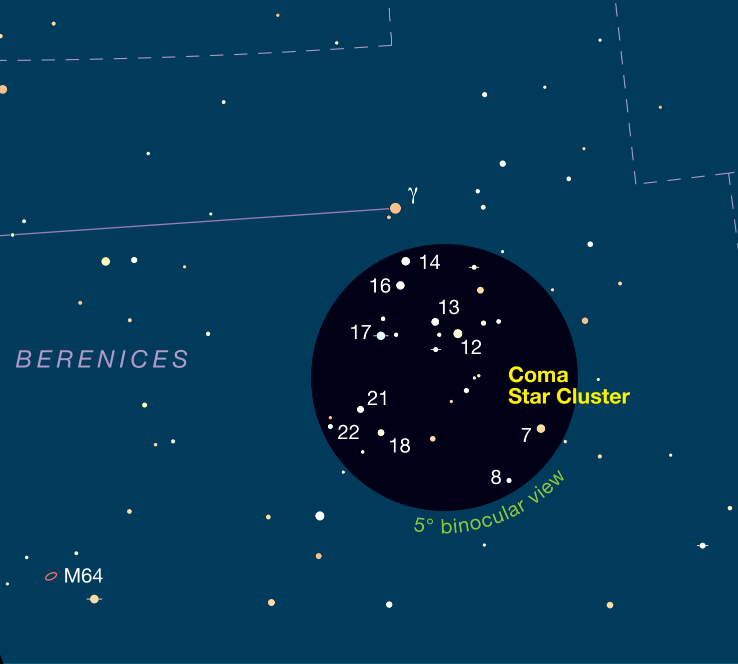
• Pascal Crater	April 2
• Hale Crater	April 18
• Helmholtz Crater	April 19
• Lyot Crater	April 20



Planet location shown for mid-month

USING THE NORTHERN HEMISPHERE MAP
Go out within an hour of a time listed to the right. Turn the map around so the yellow label for the direction you're facing is at the bottom. That's the horizon. The center of the map is overhead. Ignore the parts of the map above horizons you're not facing.





WHEN TO USE THE MAP

Late Feb	Midnight
Early Mar	11 p.m.
Late Mar	11 p.m.*
Early Apr	10 p.m.*
Late Apr	Nightfall

*Daylight-saving time

Binocular Highlight by Mathew Wedel

Best and Brightest

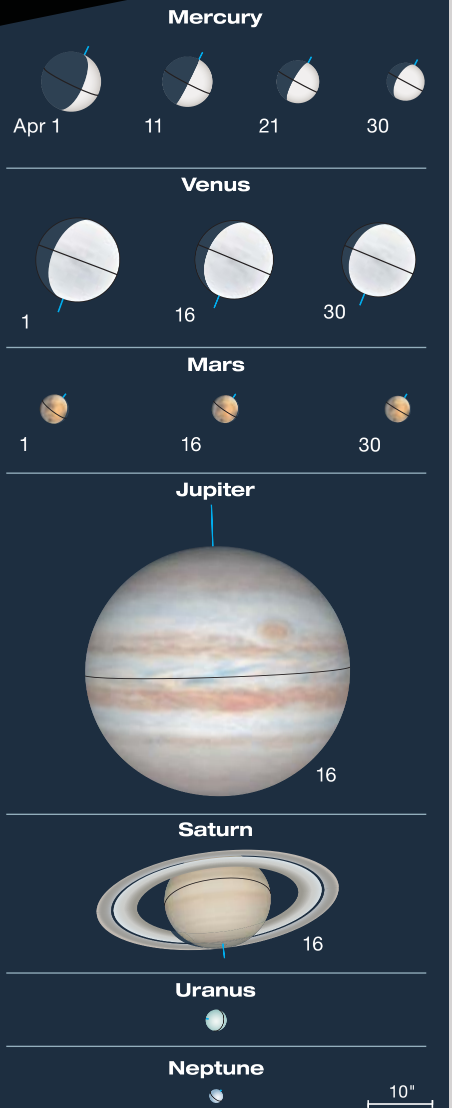
If you look east in the early evening this time of year, you should find the constellation Coma Berenices, or Berenice's Hair, which honors Egyptian queen Berenice's sacrifice of her hair to the gods.

The queen's legendary gift lies about 2° south of Gamma (γ) Comae Berenices, in the form of the **Coma Star Cluster**, the glittering jewel of the constellation for naked-eye and binocular observers. I'm not going to describe it here — I have homework for you instead. Right now, we're in the narrow springtime window in which we can catch the closest, brightest, and best star clusters in the sky at the same time in the early evening. The Coma Star Cluster is rising in the east as the Pleiades, Hyades, and Alpha Persei Cluster are all sinking toward the western horizon. This affords us the opportunity to easily compare these celestial wonders.

Closest to us at 150 light-years is the Hyades, in Taurus, the Bull. Next comes the Coma Star Cluster, at about 280 light-years, then the Pleiades at 440 light-years. The most distant of the four clusters is the Alpha Persei Cluster, which lies 600 light-years away. The Alpha Persei Cluster occupies so much sky compared to the others because it's actually immense, more than 30 light-years across. In contrast, the Coma Star Cluster is about 20 light-years across, and the Hyades and Pleiades around 15.

I urge you to spend some time comparing and contrasting these clusters with your binoculars and with your naked eyes. Whether doing so inspires you to contemplate cosmic time and distance, or simply to enjoy some of the finest sights in the night sky, it will be time well spent.

■ **MATT WEDEL** is finding it a challenge to stuff even a small star cluster into his brain. Binoculars certainly help.



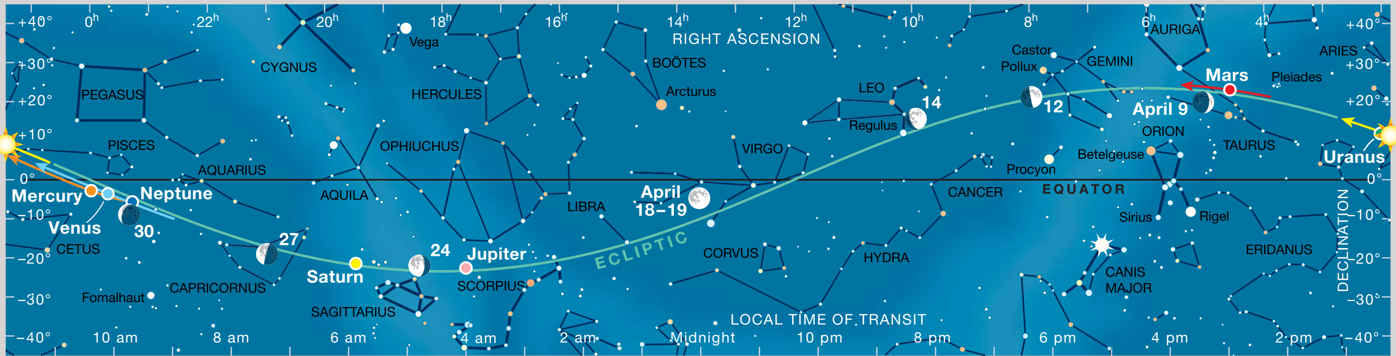
PLANET DISKS have south up, to match the view in many telescopes. Blue ticks indicate the pole currently tilted toward Earth.

PLANET VISIBILITY **Mercury:** lost in the solar glare all month • **Venus:** visible at dawn all month • **Mars:** visible at dusk, sets mid-evening • **Jupiter:** rises near midnight, visible until dawn • **Saturn:** rises early morning, visible until dawn

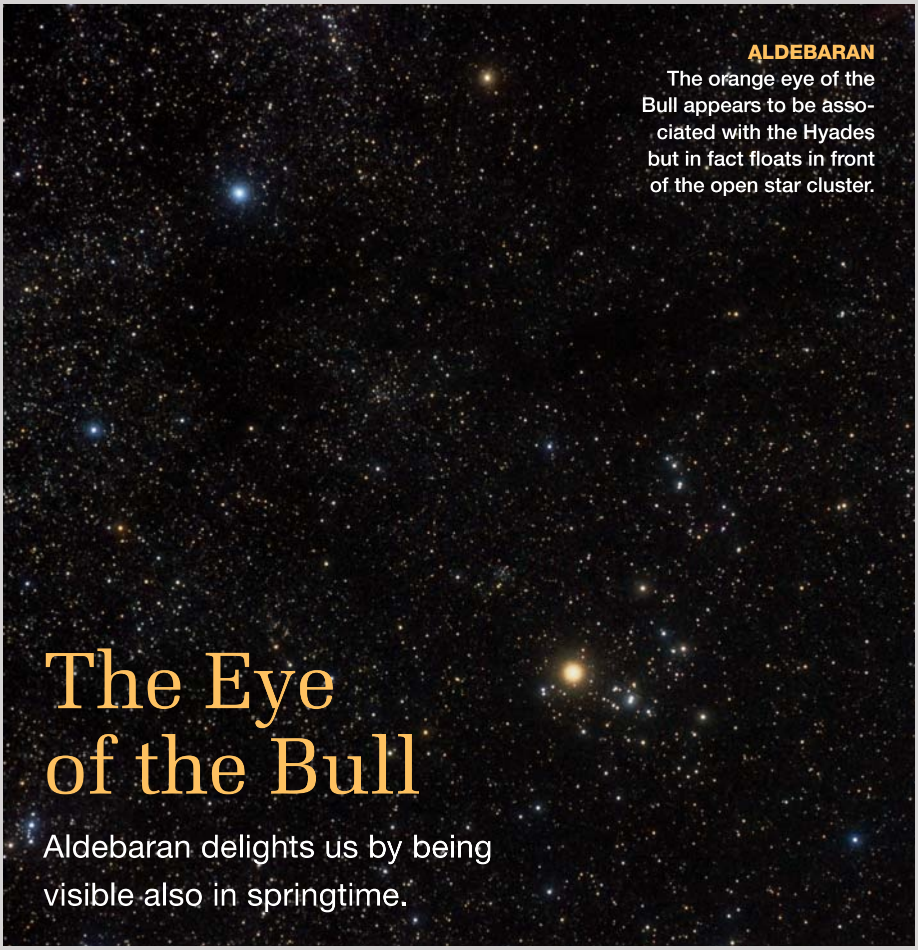
April Sun & Planets

	Date	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	0^h 39.4^m	+4° 15′	—	–26.8	32′ 01″	—	0.999
	30	2^h 26.9^m	+14° 32′	—	–26.8	31′ 46″	—	1.007
Mercury	1	23^h 10.2^m	–5° 36′	24° Mo	+0.8	9.4″	29%	0.718
	11	23^h 37.2^m	–4° 36′	28° Mo	+0.3	7.8″	47%	0.858
	21	0^h 21.0^m	–0° 40′	26° Mo	0.0	6.7″	61%	1.005
	30	1^h 10.3^m	+4° 42′	21° Mo	–0.3	5.9″	74%	1.136
Venus	1	22^h 32.4^m	–10° 10′	35° Mo	–3.9	13.1″	81%	1.274
	11	23^h 18.0^m	–5° 54′	33° Mo	–3.9	12.5″	84%	1.334
	21	0^h 02.9^m	–1° 21′	30° Mo	–3.9	12.0″	86%	1.391
	30	0^h 43.2^m	+2° 51′	28° Mo	–3.8	11.6″	88%	1.440
Mars	1	3^h 51.4^m	+21° 06′	50° Ev	+1.4	4.6″	94%	2.020
	16	4^h 33.3^m	+22° 58′	45° Ev	+1.5	4.4″	95%	2.133
	30	5^h 12.9^m	+24° 04′	40° Ev	+1.6	4.2″	96%	2.232
Jupiter	1	17^h 33.7^m	–22° 40′	107° Mo	–2.2	39.8″	99%	4.947
	30	17^h 31.8^m	–22° 39′	136° Mo	–2.4	43.4″	100%	4.547
Saturn	1	19^h 24.5^m	–21° 36′	81° Mo	+0.6	16.4″	100%	10.161
	30	19^h 27.4^m	–21° 31′	109° Mo	+0.5	17.2″	100%	9.683
Uranus	16	1^h 59.5^m	+11° 40′	6° Ev	+5.9	3.4″	100%	20.847
Neptune	16	23^h 14.9^m	–5° 54′	38° Mo	+7.9	2.2″	100%	30.720

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



The Sun and planets are positioned for mid-April; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side). "Local time of transit" tells when (in Local Mean Time) objects cross the meridian — that is, when they appear due south and at their highest — at mid-month. Transits occur an hour later on the 1st, and an hour earlier at month's end.



ALDEBARAN The orange eye of the Bull appears to be associated with the Hyades but in fact floats in front of the open star cluster.

AKIRA FUJII

The Eye of the Bull

Aldebaran delights us by being visible also in springtime.

I've written here before about the thrill of seeing Capella low in the due north in July from North Dakota. My first time was during the longest total lunar eclipse in U.S. history, whose totality for me was followed by a seemingly celebratory auroral display.

In the present column, I want to consider a 1st-magnitude star that, though much farther south than Capella, is also a star for all seasons, and almost all months. The star is Aldebaran, usually regarded as a sight of late autumn and winter. To help prove its year-round status, I'm going to discuss the special beauties Aldebaran displays in a month we don't always associate with it (April with Aldebaran) and also a month we don't ever associate with it (July with Aldebaran).

Summarizing the amazing Aldebaran. Whatever time or date you see Aldebaran, it's one of the most distinctive of all stars. It's the only very bright star (magnitude +0.9) hanging in front of a very bright star cluster (the Hyades, about twice as far from Earth as Aldebaran is). It's the 1st-magnitude star moving away from us much more rapidly than any other — at 54 km/s, faster than all but three of the more than 300 stars brighter than magnitude 3.5. It's the star that shined the brightest in Earth's night skies of any star at any time in the past 900,000 years or so (besides, currently, Sirius) — and brighter than all but two that will shine in the next 5 million years. It's the star that had a close encounter in our sky with Capella more than 400,000 years ago (when Aldebaran outshined Capella), and the two formed the most spectacular double North Star in at least millions of years. Aldebaran, an orange giant, is also a vision of what our Sun will become, but the future Sun won't be as mighty — Aldebaran's mass of perhaps up to 1.7 times that of the Sun suggests a luminosity of about 425 times current solar and a diameter around 44 times that of the current Sun.

Aldebaran in April. Aldebaran and the Hyades, an arrowhead pointing right when rising early on November evenings, at dusk is now an upright V preparing to set. Aldebaran is now also part of a horizontal line with the Pleiades to its right, and Orion's Belt and Sirius to its left. Most notably, Aldebaran (in some Aprils) is a target for Mercury and brilliant Venus. No nighttime star that can be occulted by the Moon is brighter than Aldebaran — and no such occultation more beautiful than when it happens in April with a slender, not overbearingly bright, lunar crescent.

Aldebaran and the Moon's near miss last July. July is the month when Aldebaran emerges into morning twilight to encounter many planets and lunar crescents. The grazing occultation of Aldebaran by the Moon on July 10, 2018, was the last visible in a night sky until 2033. I wasn't far enough north to catch the graze, but the near miss I observed was as beautiful as anyone could hope for.

In the dusk the day before, I enjoyed Venus and Regulus, less than 1° apart, with naked eye and binoculars, while hearing five or even six wood thrushes singing near my house. About seven hours later I went out and arrived at my favorite local pond. There I saw in the sky and reflected in the still waters the 11%-illuminated moon and, only about 4′ from the edge of its lower cusp, the twinkling point of Aldebaran. Through binoculars and a wide-field telescope that captured the main grouping of the Hyades, the twinkling point was pulsing madly with every color, including intense red — and was countered with an exquisite earthshine on the Moon's night side. As I watched, words of preposterous but delightful poetry came into my head: "With all my heart I hereby / Summon the softly glowing gray ghost of the rest of the Moon / And Aldebaran nearby."

■ Contributing Editor **FRED SCHAAF** welcomes your letters and comments at **fschaaf@aol.com**.

To find out what's visible in the sky from your location, go to skypub.com/almanac.

Planets, Bright and Minor

Five bright planets grace the skies from dusk to dawn, and a minor planet comes to opposition.

In the early evening, Mars is almost halfway up the western sky in Taurus. Mars sets in the hour before midnight and is replaced by the rising of brightening Jupiter in the east. Saturn comes up somewhat later than Jupiter, and by late April the two planets are to either side of the meridian as dawn brightens. Venus starts rising in morning twilight, with Mercury following it even lower in the dawn glow.

DUSK THROUGH EVENING

Mars sets more than 4 hours after the Sun (for viewers around latitude 40° north) as April begins, less than 3½ hours by month's end. The planet fades a bit more (magnitude 1.5 to 1.6) and shrinks a bit more (4.6″ to 4.2″ wide). But Mars takes a scenic trek through Taurus in April. It begins the month only about 3° left of the Pleiades, then spends the first week of April marching between the Pleiades and the Hyades. Not until April 16th does Mars pass 7° north of now-considerably brighter Aldebaran. At month's end Mars is still around 6° degrees lower left of Beta Tauri (El Nath) — a star that is then virtually identical to Mars in brightness.

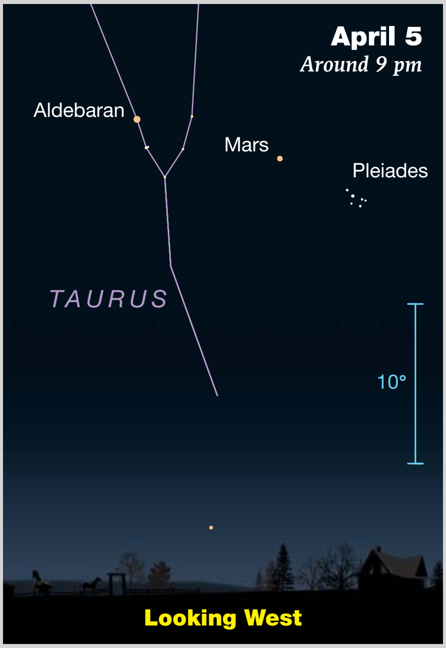
ALL NIGHT

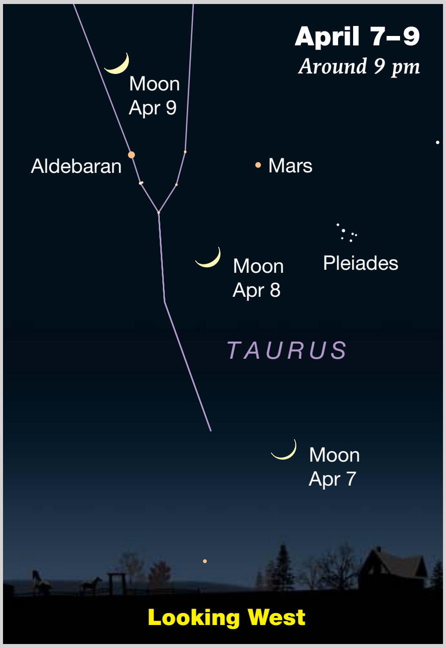
Pallas is at opposition on April 6 in Boötes near Muphrid (Eta Boötis) — see page 48 for details.

MIDNIGHT TO DAWN

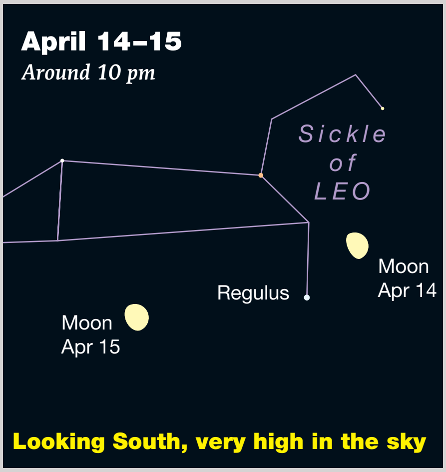
Jupiter doesn't rise until after 1 a.m. at the beginning of April. By month's end, the giant planet rises above the horizon a little after 11 p.m., just as Mars is setting. Unlike currently lackluster Mars, Jupiter dominates its region of the sky, its brightness improving from magnitude –2.3 to –2.5 in April. Jupiter is best seen, especially in telescopes, when it's at its highest in the south, which happens about 1 to 2 hours before sunup this month. Jupiter's apparent equatorial diameter does increase from 40″ to more than 43″ during the month. On April 10th, exactly two months before Jupiter reaches opposition, the gas giant begins retrograde motion, starting to head slowly westward relative to the background stars of Ophiuchus. This movement will bring Jupiter back much closer to Antares by early summer, but in April the planet seems to hover about 15° left or upper left of the star in the early morning sky.

Saturn comes up around 3 a.m. on April 1st but about 1 a.m. on April 30th.

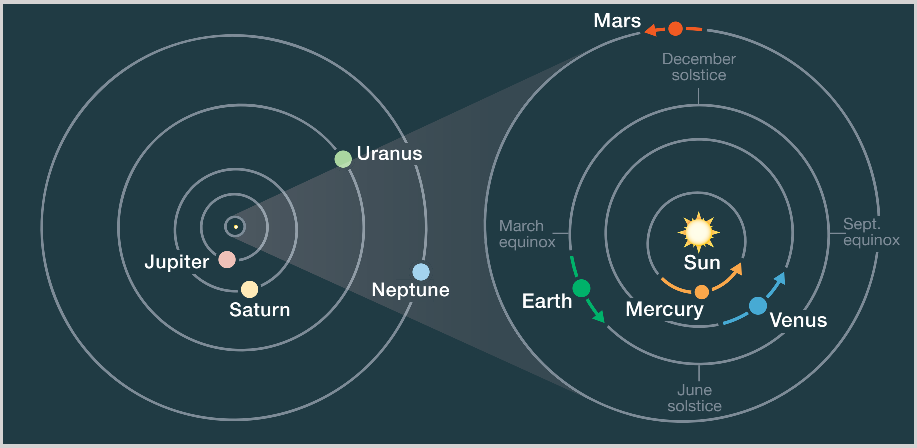




◀▼▶ These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west); European observers should move each Moon symbol a quarter of the way toward the one for the previous date. In the Far East, move the Moon halfway.



The splendor-ringed world is in eastern Sagittarius, its brightness increasing from magnitude +0.6 to +0.5 during the month. Saturn begins April less than 26° from Jupiter, but as the latter starts retrograding away from Saturn the gap increases to almost 27° by month's end. Actually, on April 29th in the Americas, Saturn begins its own retrograde motion. Since Saturn's movement is much slower than Jupiter's, however, the two will continue to separate from each other for several more months. At the end of April, Saturn reaches the meridian just a few minutes before sunrise. Morning twilight is the best time to point a telescope at Saturn this month, catching its disk growing slightly to 17″ and its rings continuing to be highly tilted and lovely.



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

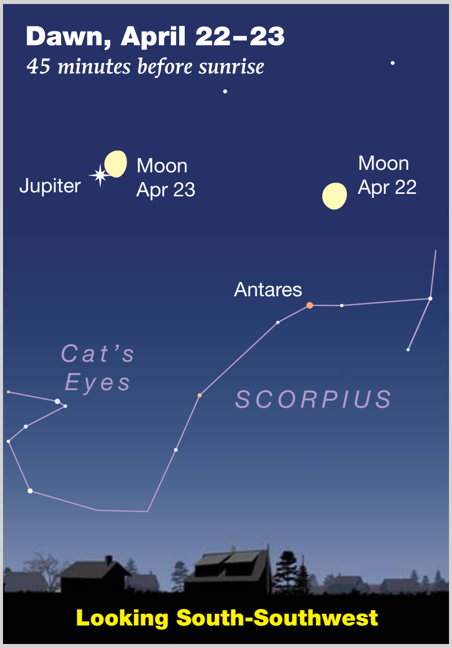
DAWN

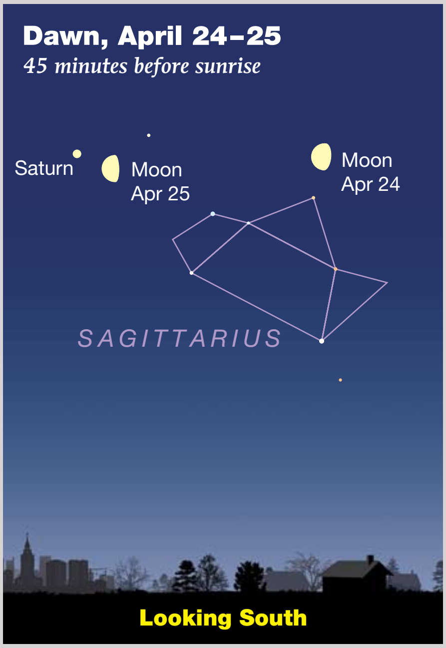
Venus and **Mercury** both rise during morning twilight and form a fascinating pair this month — but unfortunately they are quite low in the east-southeast for observers at mid-northern latitudes. Mercury, specifically, is never higher than 5° at civil twilight. Venus comes up first, a beacon of magnitude –3.9 appearing less than 12″ across and about 88% illuminated by month's end. As April opens, Mercury rises about an hour before the Sun (but shines at only magnitude +0.9 — use binoculars!) and as the month ends only about 40 minutes before the Sun (though by then Mercury has brightened to –0.3). Mercury reaches a greatest western elongation of 28° from the Sun on April 11th.

What's perhaps most interesting about Mercury and Venus this month is their separation. On April 1st these two planets are about 10° apart. The gap between them shrinks pretty rapidly, but Mercury falls back towards the Sun before Venus can catch it and have a conjunction in right ascension. Instead, what happens is a "quasi-conjunction" — a pairing of less than 5° separation that occurs without a true conjunction. In this case, the quasi-conjunction (the first between planets in almost three years) occurs on April 16th when Mercury and Venus are about 4⅓° apart.

Neptune is just emerging from the solar glare at dawn in April, but if you have a telescope, clear skies, and a sharp eye you may catch the 8th-magnitude world a little more than ⅓° north of Venus on the morning of April 10th in the Americas.

Uranus is at conjunction with the Sun on April 22nd and is therefore lost in the solar glare all month.





MOON PASSAGES

The Moon is a very thin, waning crescent some 8° right of Venus on April 1st at dawn in the Americas. The waxing lunar crescent is far below Mars and the Pleiades on the evening of April 7th but forms a quite compact and almost equilateral triangle with them the next night. The Moon is 5° above Aldebaran on April 9th. The waxing gibbous Moon is 5° or 6° from Regulus on the night of April 14–15. The waning gibbous Moon is 1° from Jupiter on the morning of April 23rd and 2° lower right of Saturn on the morning of April 25th.

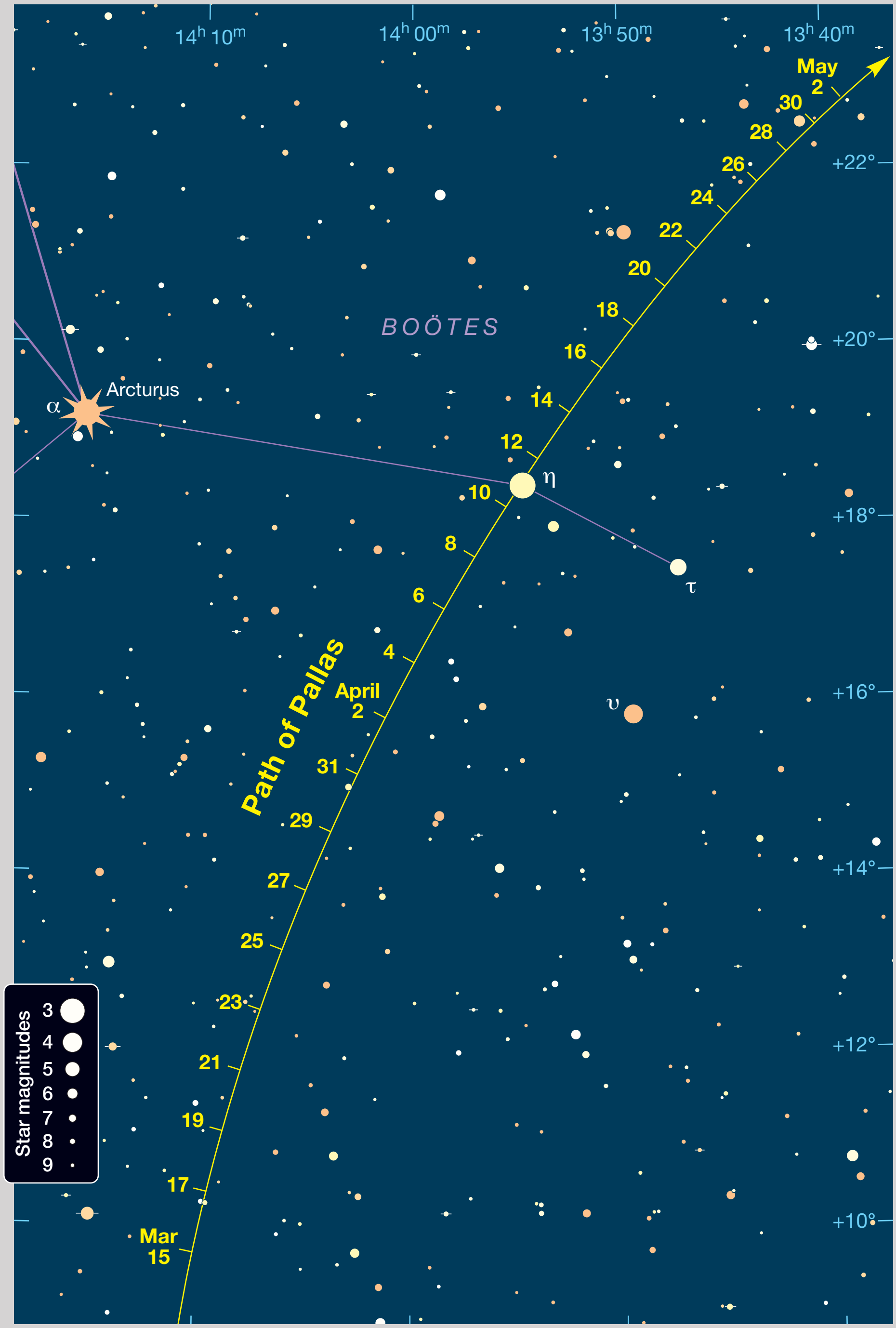
■ Contributing Editor **FRED SCHAAF** had the 10-mile-wide asteroid 7065 Fredschaaf named after him in 2016.

An April Asteroid

Try to catch 2 Pallas as it skims through the northern sky this month.

Conditions are ideal for viewing asteroid 2 Pallas as it eases its way across Boötes this month. Opposition falls on April 6th, just 32 hours after new Moon; however, Pallas is well placed for observation in the weeks preceding and following that date as well. Pallas spends most of March and April just 1.6 astronomical units from Earth, making its closest approach March 29–30, and rises to a peak brightness of 7.9 on March 20th. Look for it to remain that bright through April 14th. After that date, it slowly dims, dropping to magnitude 8.5 by May 11th. Pallas won't approach naked-eye visibility any time soon (it's not predicted to bump up to an estimated magnitude 6.6 before March 2028), but even at magnitude 8.5 it's well within reach of 10×50 binoculars and small telescopes.

Pallas was first detected by the German astronomer Heinrich W. M. Olbers. Trained as a physician, Olbers was also a dedicated astronomer who spent his nights observing from the upper floor of his home in Bremen (bay windows gave him a clear view to the south, and he knocked holes in the roof to allow zenithal observations). On March 28, 1802, he passed some of the evening studying Ceres, the only asteroid known at that point, through his Dollond refractor. Those observations completed, he turned his telescope to the adjacent sector of sky. To his surprise, he almost immediately spotted a star where he knew none should



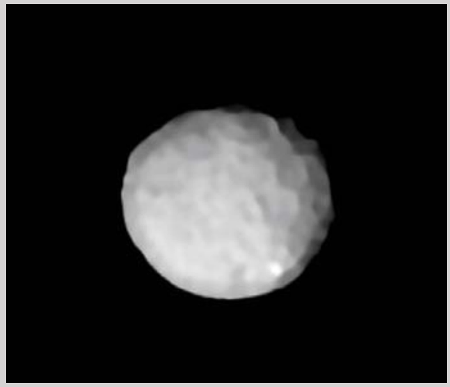
Asteroid 2 Pallas follows a shallow arc across southwest Boötes in April. Use the 3rd-magnitude star Eta (η) Boötis to locate the asteroid near the date of opposition.

be. He noted the star's position, and when he checked back less than three hours later, it had changed in relation to the background of "fixed stars." He observed the "moving star" again the next night, then fired off an observing report to colleagues.

In a letter that eventually made its way to William Herschel in England, Olbers indicated that he'd had difficulty estimating the object's brightness. "The new planet appears as a star between the 5th and 6th magnitude," he wrote, "and in the telescope, at least with the magnifications I can apply, is indistinguishable from a fixed star." The astronomer-mathematician Carl Friedrich Gauss calculated the elements of the object's orbit and discovered that it was roughly the same distance from the Sun as Ceres (a mean of 2.8 a.u.). This led Olbers to suspect that Pallas, like Ceres, was the remnant of some destroyed planet that once orbited between Mars and Jupiter. Although we now favor theories that assign asteroids to a protoplanetary disk, it's easy to see how the discovery of the first asteroids could lead astronomers toward this conclusion.

For observers at mid-northern latitudes, Pallas rises in daylight so becomes visible with the darkness of mid-evening and remains so all night. On April 6th, find it about 23° above the eastern horizon around 9 p.m. local daylight-saving time. Pallas stands highest, about 67° high in the southern sky, around 2 a.m. but is still about 40° high in the west as it disappears in morning twilight.

Pallas moves relatively quickly across the field of background stars, so you should be able to detect a change in its position over the course of just a few hours. Plan to observe it more than once, either on the same night or on the next clear evening, to verify your observations (do as Olbers did!). Several dimmer stars lie near the asteroid's path in March and April, and a detailed sketch will make it easier to compare the asteroid's positions as they change over time. Eta (η) Boötis is an easy star-hop from Arcturus. Between April 8th and 12th or so, Eta serves as a good finding aid for the asteroid.



▲ Because of the asteroid's inclined orbit, we've yet to send a spacecraft to survey Pallas. The Hubble Space Telescope and other, ground-based systems have imaged the asteroid, but our best look at it to date comes from the Spectro-Polarimetric High-Contrast Exoplanet Research instrument on the Very Large Telescope (VLT) at the European Southern Observatory in Paranal, Chile. Pallas's rocky, irregular globe is approximately 510 km wide.

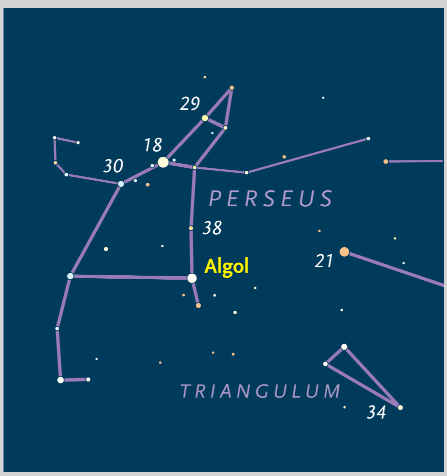
ESO / VERNAZZA ET AL.

● **FIND YOUR CLUB:** **skyandtelescope.com/astronomy-clubs-organizations.**

No Lyrids for Now

THE LYRID METEOR SHOWER is predicted to peak on the night of April 21–22. Unfortunately, that's not long after April 19th's full Moon, which means the view will be compromised by moonlight. Even so, it's worth scanning the skies for meteors. The Lyrids aren't generally known for high meteor counts, usually numbering some 10–20 per hour, but fireballs have been reported in the past. And there have been a few times, most notably in 1922 in Poland and 1982 in North America, when the shower produced hundreds of meteors per hour. For observers in the Northern Hemisphere, the radiant, on the border between Hercules and Lyra, is low on the northeastern horizon at dusk and continues to rise throughout the night.

FOLLOW THE SHOWER ONLINE: As meteor observers report their counts to the IMO, you can watch this year's Lyrid activity curve develop hour by hour at imo.net.



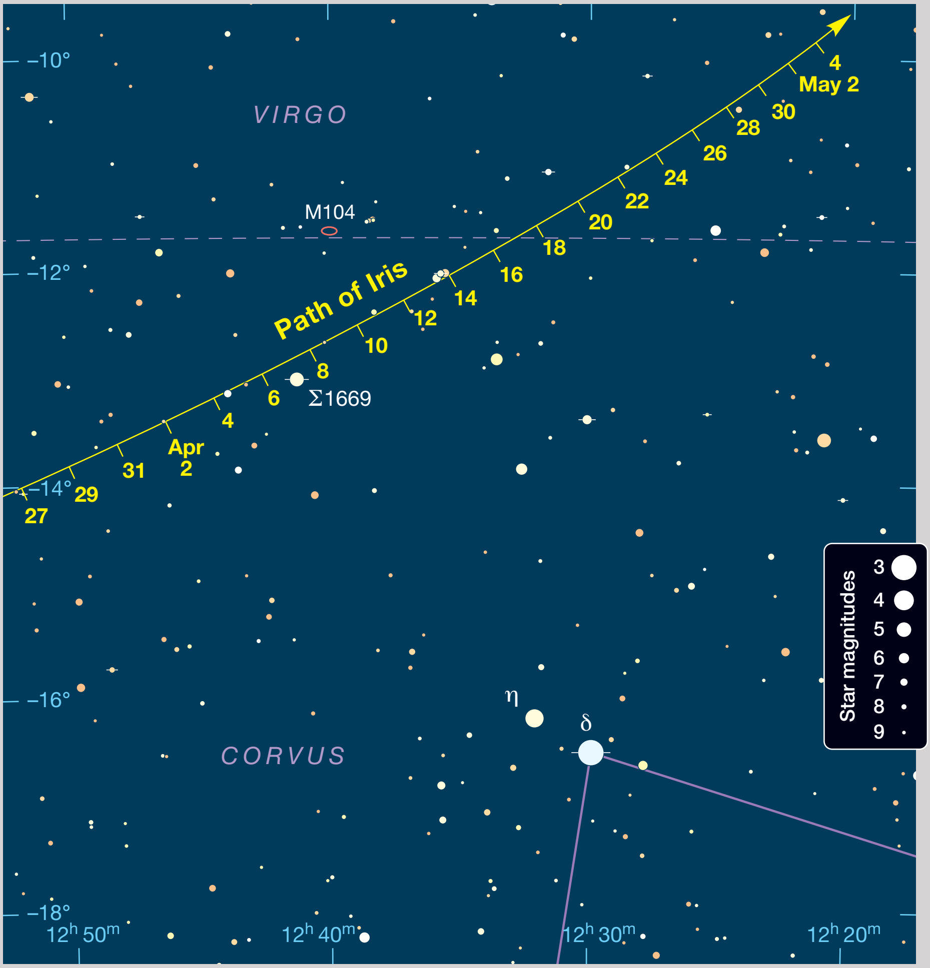
▲ As spring deepens, Perseus sets earlier, making April the last practical month for evening observation until autumn. Every 2.7 days, Algol (Beta Persei) dips from its usual magnitude 2.1 to 3.4 and back. Use this chart to estimate its brightness in respect to comparison stars of magnitude 2.1 and 3.4.

Minima of Algol

Mar.	UT	Apr.	UT
2	0:19	2	13:21
4	21:09	5	10:10
7	17:58	8	7:00
10	14:47	11	3:49
13	11:36	14	0:38
16	8:26	16	21:27
19	5:15	19	18:16
22	2:04	22	15:05
24	22:54	25	11:54
27	19:43	28	8:44
30	16:32		

These geocentric predictions are from the recent heliocentric elements Min. = JD 2445641.5540+ 2.867324*E*, where *E* is any integer. For a comparison-star chart and more info, see **skyandtelescope.com/algol**.

Another Asteroid



▲ Asteroid 7 Iris heads into Virgo in the last half of April. Star-hop from Spica or Delta (δ) Corvi to the multiple-star system Σ1669; from there, start your hunt for the 9th-magnitude asteroid.

ONCE YOU'VE WARMED UP with Pallas, turn your scope to the southwest to find asteroid 7 Iris. This small object — it sports a diameter of about 200 km, less than half that of Pallas — reaches opposition on April 5th. On that date, Iris is curling through northeastern Corvus, headed toward Virgo. Serendipitously, several stars lie on or near the asteroid's path. Use Spica or Delta (δ) Corvi to find Iris's general location; the multiple star Struve 1669 (Σ1669) is a good place to start your final star-hop.

Iris is the fourth-brightest asteroid, but intrinsic brightness doesn't always translate to easy visibility. At opposition, Iris shines only at magnitude 9.4, still within range of small scopes but far dimmer than the 6.9-magnitude light we saw in 2017. Mark your calendars for October 2028, when Iris is predicted to shine at magnitude 7.0.

Iris becomes visible for observers at mid-northern latitudes in mid-evening and reaches an altitude of some 20° in the southeast before 10 p.m. local daylight-saving time. Iris is highest, around 35°, in the hour after midnight.

Action at Jupiter

JUPITER RISES about 1 a.m. local daylight-saving time at the beginning of April. The giant planet, beaming at magnitude –2.3, is difficult to miss as it rises in the southeast with Ophiuchus. Jupiter grows even brighter over the course of the month, reaching magnitude –2.5 by April 30th. Jupiter's equatorial diameter also expands from 40″ to 43″ in April.

Any telescope shows the four big Galilean moons, and binoculars usually show at least two or three. Use the diagram on the facing page to identify them at any date and time.

All of the April interactions between Jupiter and its satellites and their shadows are tabulated on the facing page. Find events timed for when Jupiter is at its highest in the early morning hours.

Here are the times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian. The dates, also in UT, are in bold. (Eastern Daylight Time is UT minus 4 hours.)

March 1: 7:14, 17:10; **2:** 3:05, 13:01, 22:57; **3:** 8:52, 18:48; **4:** 4:44, 14:40; **5:** 0:35, 10:31, 20:27; **6:** 6:22, 16:18; **7:** 2:14, 12:09, 22:05; **8:** 8:01, 17:56; **9:** 3:52, 13:48, 23:43; **10:** 9:39, 19:35; **11:** 5:31, 15:26; **12:** 1:22, 11:18, 21:13; **13:** 7:09, 17:05; **14:** 3:00, 12:56, 22:52; **15:** 8:47, 18:43; **16:** 4:39, 14:34; **17:** 0:30, 10:26, 20:21; **18:** 6:17, 16:13; **19:** 2:08, 12:04, 22:00; **20:** 7:55, 17:51; **21:** 3:47, 13:42, 23:38; **22:** 9:34, 19:29; **23:** 5:25, 15:21; **24:** 1:16, 11:12, 21:08; **25:** 7:03, 16:59; **26:** 2:55, 12:50, 22:46; **27:** 8:42, 18:37; **28:** 4:33, 14:29; **29:** 0:24, 10:20, 20:15; **30:** 6:11, 16:07; **31:** 2:02, 11:58, 21:54.

April 1: 7:49, 17:45; **2:** 3:41, 13:36, 23:32; **3:** 9:28, 19:23; **4:** 5:19, 15:14; **5:** 1:10, 11:06, 21:01; **6:** 6:57, 16:53; **7:** 2:48, 12:44, 22:40; **8:** 8:35, 18:31; **9:** 4:26, 14:22; **10:** 0:18, 10:13, 20:09; **11:** 6:05, 16:00; **12:** 1:56, 11:51, 21:47; **13:** 7:43, 17:38; **14:** 3:34, 13:30, 23:25; **15:** 9:21, 19:16; **16:** 5:12, 15:08; **17:** 1:03, 10:59, 20:55; **18:** 6:50, 16:46; **19:** 2:41, 12:37, 22:33; **20:** 8:28, 18:24; **21:** 4:19, 14:15; **22:** 0:11, 10:06, 20:02; **23:** 5:57, 15:53; **24:** 1:49, 11:44, 21:40; **25:** 7:35, 17:31; **26:** 3:27, 13:22, 23:18; **27:** 9:14, 19:09; **28:** 5:05, 15:00; **29:** 0:56, 10:52, 20:47; **30:** 6:43, 16:38.

These times assume that the spot will be centered at System II longitude 300°. If the Red Spot has moved elsewhere, it will transit 1⅔ minutes earlier for each degree less than 300° and 1⅔ minutes later for each degree more than 300°.

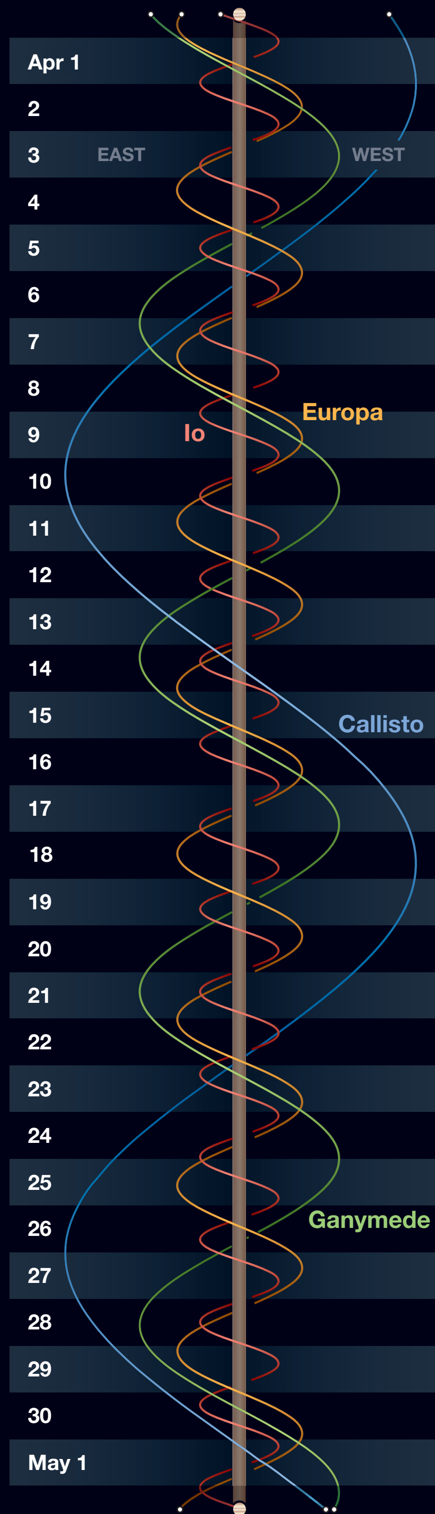
Features on Jupiter appear closer to the central meridian than to the limb for about 50 minutes before and after transiting. A light blue or green filter slightly increases the contrast and visibility of Jupiter's reddish and brownish markings.

Phenomena of Jupiter's Moons, April 2019

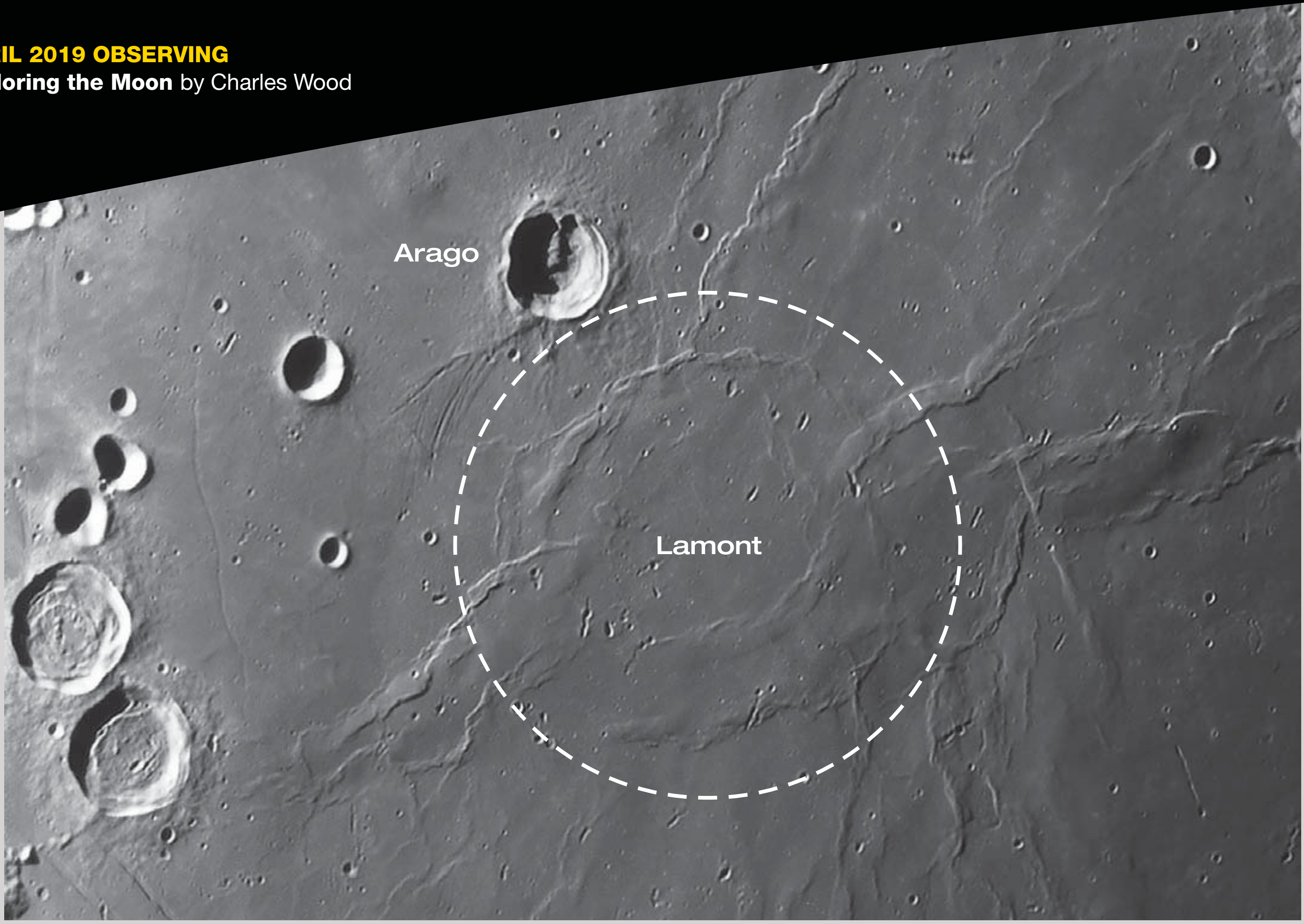
Apr. 1	10:10	I.Ec.D
	10:39	II.Sh.I
	11:54	III.Sh.I
	13:01	II.Sh.E
	13:01	II.Tr.I
	13:34	I.Oc.R
	14:03	III.Sh.E
	15:24	II.Tr.E
	16:49	III.Tr.I
	18:59	III.Tr.E
Apr. 2	7:25	I.Sh.I
	8:38	I.Tr.I
	9:36	I.Sh.E
	10:49	I.Tr.E
Apr. 3	4:38	I.Ec.D
	5:19	II.Ec.D
	7:44	II.Ec.R
	7:47	II.Oc.D
	8:01	I.Oc.R
	10:14	II.Oc.R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

Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 4 hours ahead of Eastern Daylight Time). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede, or **IV** Callisto. Next is the type of event: **Oc** for an occultation of the satellite behind Jupiter's limb, **Ec** for an eclipse by Jupiter's shadow, **Tr** for a transit across the planet's face, or **Sh** for the satellite casting its own shadow onto Jupiter. An occultation or eclipse begins when the satellite disappears **(D)** and ends when it reappears **(R)**. A transit or shadow passage begins at ingress **(I)** and ends at egress **(E)**. Each event is gradual, taking up to several minutes. Predictions courtesy IMCCE / Paris Observatory.

Jupiter's Moons



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



Lamont: The Shadow Knows

Did NASA's GRAIL mission reveal the true identity of a ghostly lunar feature?

Lamont Cranston was an identity sometimes taken by the main character of "The Shadow," a serialized radio drama that came on the air in the 1930s. The Shadow had the ability to "cloud men's minds," and every broadcast ended with an ominous voice saying, "The Shadow knows!"

Much like the fictional character, the lunar feature **Lamont** has clouded the minds of many observers and scientists, for it is unlike any other landform on the Moon. Barely noticed by early lunar mappers, the feature wasn't named until 1898 by the young Bavarian observer Johann Nepomuk Krieger, who added visually observed details to Lick and Paris Observatory photographs. Today, fine amateur images reveal that Lamont is a complex of concentric and radial ridges, difficult to see unless the terminator is nearby. Lamont looks like a 75-kilometer-wide (47-mile-wide) ghost crater, a pre-existing feature completely covered by subsequent lava flows in **Mare Tranquillitatis** (*S&T:* June 2018, p. 53).

But Lamont is more than a ghostly ring. It's partially surrounded by a discontinuous outer ring about 135 km in diameter, making it appear like the specter of a two-ring impact basin. U.S. Geological Survey geologist David Scott proposed this in 1974 when it was discovered that a moderate-size *mascon* was centered at Lamont. Mascons are circular gravity highs — an excess of mass. Mascons are centered on circular impact basins and are believed to have two origins: The rebound of dense lunar

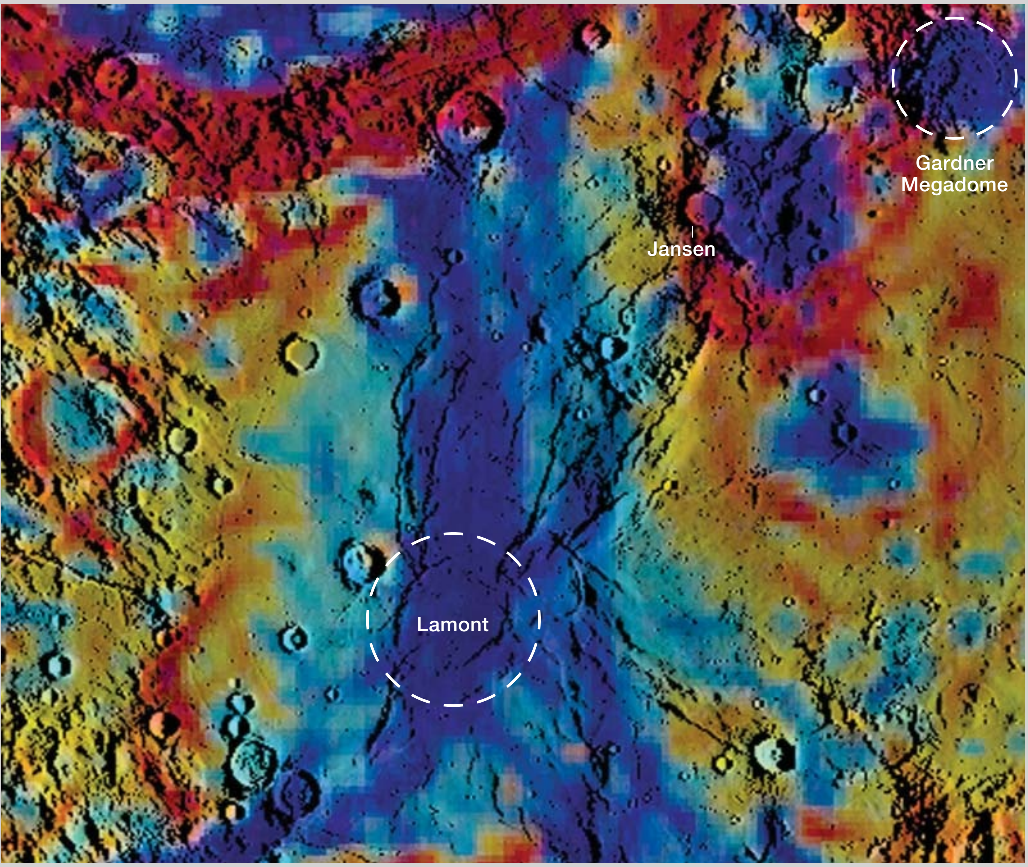
▲ Lamont is commonly thought to be an ancient crater almost completely buried by lava in Mare Tranquillitatis, visible only under low-Sun illumination. Or is it a volcanic structure?

mantle material during the formation of impact basins, and the mass of kilometer-thick piles of later mare fill.

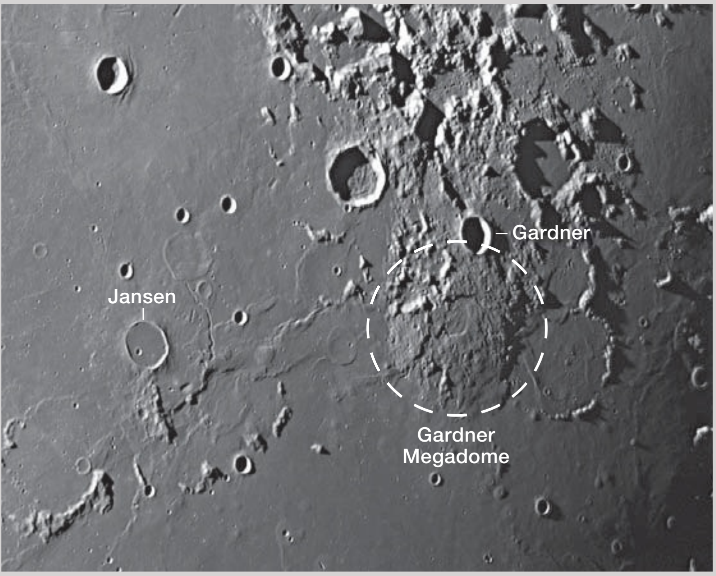
The fact that five large mare ridges radiate from Lamont is strange. Impact basins don't have such ridges, so perhaps the impactor that created Lamont just happened to land at an intersection of mare ridges. My mind feels clouded . . .

Today, new information provides answers — or an expanded array of questions. NASA's GRAIL (Gravity Recovery and Interior Laboratory) spacecraft measured the gravity field of the entire Moon to high precision.

LAMONT: WESLEY HIGGINS; GRAVITY MAP: NASA / LUNAR RECONNAISSANCE ORBITER / JPL-CALTECH / MIT / GSFC / M. COLLINS; GARDNER MEGADOME: JOCELYN SEROT



◀ NASA's LRO topographical data combined with the GRAIL gravity map reveals excess gravity signal coinciding with Lamont and mare ridges that run to the north and south.



◀ The Gardner Megadome is another volcanic landform located just south of the crater Gardner. To the west the lava-floored crater Jansen sits on a rille-crossed volcanic plateau.

Mascons and many other previously unknown gravitational features were mapped out in great detail. By looking not just at the gravity values but their rate of change, GRAIL scientists discovered entirely new features. Most are enigmatically long, narrow lines of excess gravity that GRAIL scientists propose represent subsurface dikes, vertical sheets of magma that fractured the crust and rose from deeper sources toward the surface.

Maurice Collins, coauthor of our book *21st Century Atlas of the Moon*, has combined the GRAIL gravity data and Lunar Reconnaissance Orbiter (LRO) low-illumination topography for western Mare Tranquillitatis. The blue excess gravity "worms," as I call them, coincide almost exactly with Lamont and the major mare ridges to the north and south. An impact basin wouldn't normally be associated with radial ridges that we see on the surface and their presumed underlying magma-filled dikes. But it's common on Earth for large volcanic centers such as caldera magma chambers to have fractured the surrounding crust and to have forced magma radially outward as dikes. Is Lamont a buried caldera rather than a buried impact basin?

Such an outrageous idea is consistent with two other likely volcanic landforms in this region that also have significant excess mass. The first is the **Jansen** complex about 330 km to the northeast of Lamont. Jansen is a 24-km-wide circular crater nearly filled with dark lava. It is part of an irregular plateau that's 200 to 300 meters high and 85 km wide in Mare Tranquillitatis. A small rille and a few rimless collapse depressions demonstrate that volcanism occurred near Jansen as well as inside it.

The second likely volcanic landform is a mountain about 1,000 to 1,200 m high and 70 km wide with a caldera-like central depression, 150 km northeast of the Jansen complex. When I discovered this feature 19 years ago I called it the Gardner Megadome, after nearby **Gardner** crater, and also because it looks like many smaller volcanic domes that occur in maria.

Neither the Jansen area nor the Gardner Megadome is an impact structure. Both are clearly volcanic landforms, and like Lamont, both have strong mass excesses. Nearly two decades ago I proposed that all three are large volcanic complexes and are aligned along some tectonic feature. With the GRAIL gravity worms we now see that all appear to have dikes that brought up magma to feed them. So perhaps the Shadow isn't the only one to know!

■ Contributing Editor **CHUCK WOOD** has studied the Moon for more than five decades as both an amateur astronomer and professional scientist.

Small-Scope Galaxies

Turn your optics toward these intriguing "island universes."

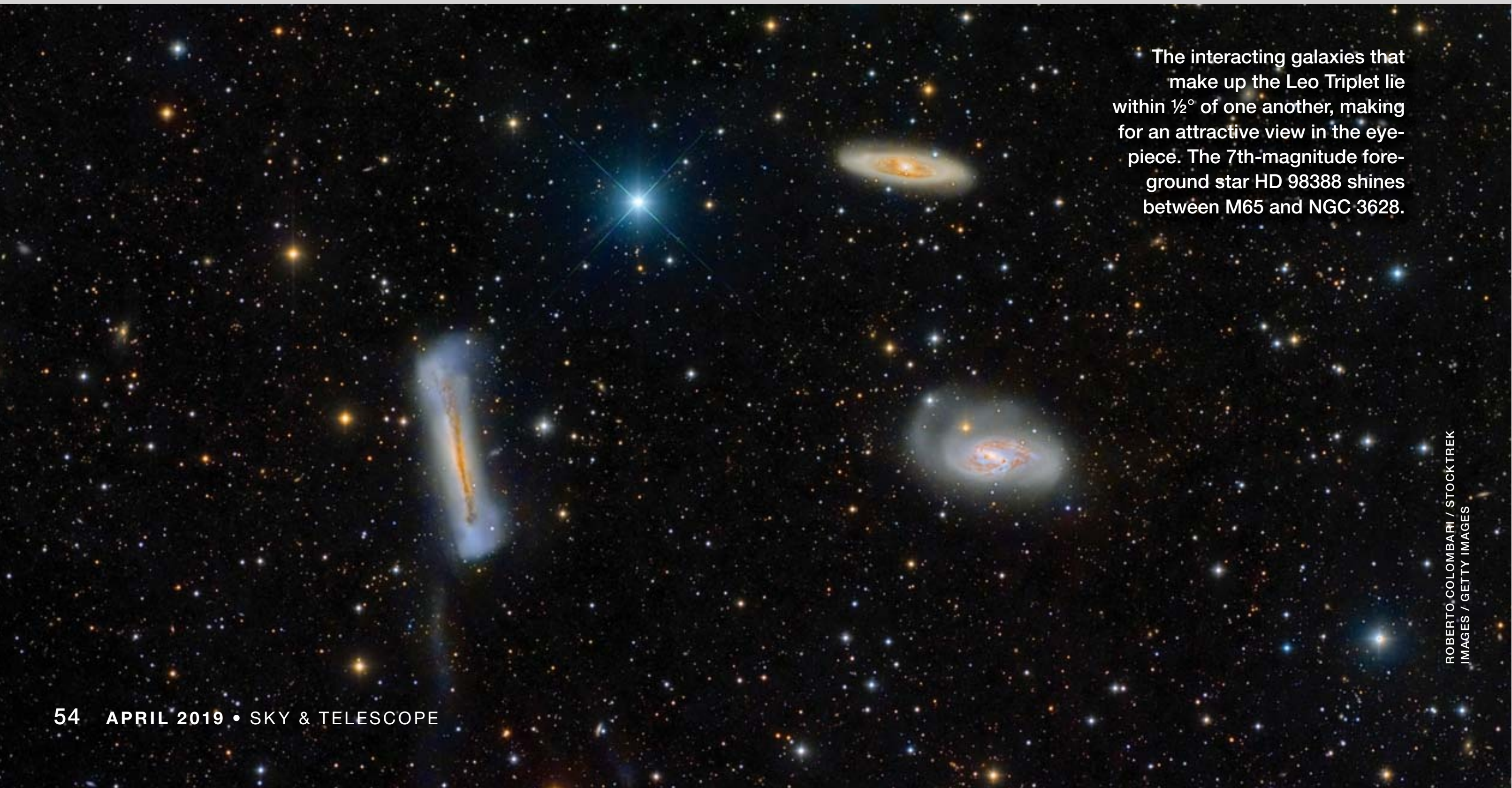
One thinker gazed upon the distant sky
Until he dreamed the Cosmos' mystic dream.
He watched the "Pageant of the Stars" go by
And caught the faint and fascinating gleam
Of island universes, nebulae.
—Lisa Oland, *The Star-Gazer*, 1937

Revolutionary ideas on the nature of the heavens were heartily tossed about early last century. Dutch-American astronomer William J. Luyten discussed these concepts in his 1928 book *The Pageant of the Stars*, where he wrote: "We see the abysmal chasms of space strewn with countless 'island universes,' vast conglomerations of matter far beyond the confines of the Milky Way." Today we call them galaxies.

The origin of the term "island universes" as used for external galaxies has long intrigued and confused me, for the matter is far from simple. Tackling the problem once more for this article, I was thrilled to find that Tom Siegfried of *Science News* had already untangled the twisted strains of this story. Credit is most commonly given to philosopher Immanuel Kant, who in 1755 reasoned that some "nebulae" were distant systems akin to our Milky Way, but he didn't call them islands. Although others have been nominated for father of this phrase, its most likely origin may surprise you — Ormsby MacKnight Mitchel, founder of the Cincinnati Observatory. Mitchel frequently used the expression "island universe" in his popular lectures and in his magazine, *The Sidereal Messenger*, which pioneered the term in 1846. The whole, fascinating story can be read at **https://is.gd/SNIslandUniverse**.

Observers often think of galaxies as prey for large telescopes, but with patient study you'll find quite a few that reveal their charms to small scopes. All shown here were observed with my 130-mm refractor from my semirural home, but the sketches were later contrast-enhanced to help you pick out features you might try to see. They appear much more subtle at the eyepiece.

Our first small-scope galaxies are **Messier 81** and **Messier 82**, seen as a pair of dust bunnies just behind the Big Bear's ear (24 Ursae Majoris) through my 9×50 finderscope. Some observers have even been able to spot M81 with the unaided eye. They're nice and bright at 23×, more so M81 with a prominent core that intensifies toward the center, whereas M82's signature cigar shape looks patchily luminous. Zooming in on each galaxy at 164×, M81 hosts a small nucleus ensconced in a fleecy core. South of the core, two foreground stars are pinned to M81's face. A pair of spiral arms can be teased from the haze, each one winding about halfway around the galaxy. M82 is gorgeous, displaying obvious dark lanes and bright patches. Its ruffled façade is likely due to a close



The interacting galaxies that make up the Leo Triplet lie within ½° of one another, making for an attractive view in the eyepiece. The 7th-magnitude foreground star HD 98388 shines between M65 and NGC 3628.

ROBERTO COLOMBARI / STOCKTREK IMAGES / GETTY IMAGES encounter with M81 a few hundred million years ago. The tidal effects triggered a tremendous burst of star formation in M82, stars whose fierce stellar winds and supernova explosions are flinging gas and dust out of the galaxy. The slow dance of future encounters may ultimately merge the pair into a single galaxy in the remote future.

Now that we've seen our pair, let's go for three of a kind in the guise of the Leo Triplet, composed of **Messier 65**, **Messier 66**, and **NGC 3628**. The trio is pretty even at 23×, sitting 1° east of 73 Leonis. M65 and M66 appear bright, and NGC 3628 is nicely visible as an elongated streak. As shown in my sketch with a wide-angle eyepiece giving 102×, the galaxies are most fetching when sharing the field of view, but they surrender more detail when examined individually at 164×. M66's core tips north-northwest, holding a bright elongated center. Delicate hints of spiral arms sprout from each end of the core, unwrapping counterclockwise in my mirror-reversed view. M65 bares a roundish core with a small brighter center. The brightest area of NGC 3628 stretches across 7′, while fainter tips that are best seen with averted vision extend the length to 11′.

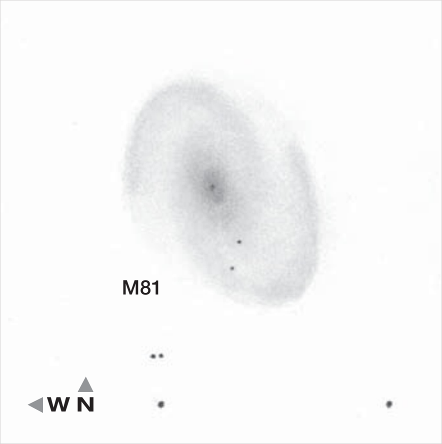
Gravitational interactions have left their mark on the Triplet. M66 boasts spiral arms that twist above the galaxy's disk and an offset core. Even more mussed, NGC 3628 has oddly flared ends as well as a tidal tail of gas and stars extending roughly a half million light-years. The tail's tip is punctuated by Leo-TDG, thought to be a tidal dwarf galaxy formed from the tail's debris.

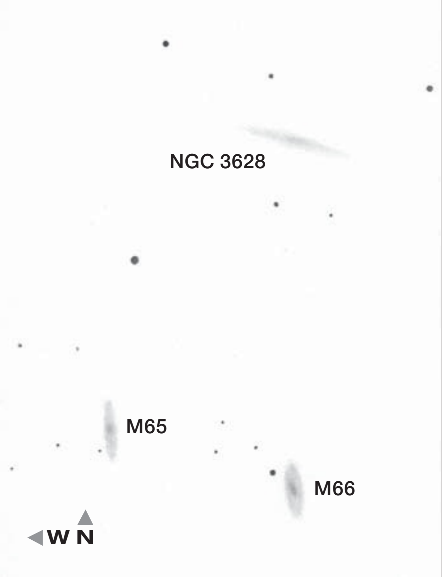
The Whirlpool Galaxy, **NGC 5194**, in Canes Venatici is one of the best targets in which to seek out spiral structure. As a bonus, its interacting companion **NGC 5195** enhances the scene. Together they're known as Messier 51. These galaxies are an easy catch at 23×, each one sporting a relatively large core. At 164× a bright nucleus dwells at the heart of each galaxy. NGC 5194's arms can be traced fairly well, but not with the detail afforded by larger scopes. One of the arms reaches out toward its companion, yet remains beyond its grasp. Images seem to show the Whirlpool's northern spiral arm latched onto its companion, but this is an illusion. NGC 5195 is tumbling by its larger neighbor, and we merely see the arm superimposed on the receding companion. The Whirlpool's pronounced, two-armed spiral structure may have been induced by the gravitational effects of an earlier encounter.

Way over on the opposite end of the Big Bear from M81 and M82, **Messier 101** is an intriguing galaxy for a small telescope. At 23× its large, diaphanous glow brightens only slightly toward the center. On a good night, a magnification of 164× coaxes out three spiral arms. A 13th-magnitude star sits 1.3′ north-northeast of the small nucleus. At low magnification the galaxy spans roughly ¼°, but the outer reaches seem to fade away at 164×, so my sketch on the next page only covers the central 9′ of the galaxy. On very good nights, better than the two I had for this sketch, I've been able to nab a few of the brightest star-forming regions in M101's outlying arms, notably NGC 5471, NGC 5462, NGC 5461, and the combined glow of NGC 5447 and NGC 5450. In addition to favorable skies, it takes patience and the judicious use of averted vision to hunt these down. If you'd like to tackle the project, you'll find a labeled chart to help you on *S&T*'s website (**skyandtelescope.com**). Just enter "Guide to Messier 101" in the search box.

Let's end our tour with **NGC 5907** in Draco, a lovely example of a flat galaxy — a disk-shaped galaxy that's seen edge-on from our vantage point on Earth and has little or no central bulge. I find these celestial toothpicks of light quite appealing. Although fairly faint, the slender glow of NGC 5907 can be seen tipped north-northwest at 37×. Examining it at 102×, I can follow its length for about 8′, shining faintly at the tips and growing softly brighter toward the center. Folks with 8-inch or larger scopes should look for this remarkable galaxy's dust lane.

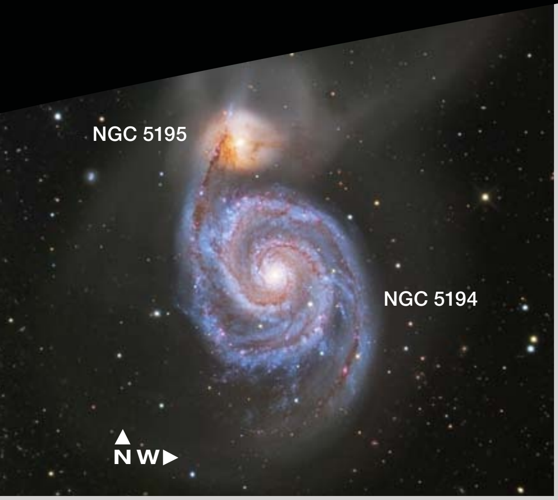
Deep images of NGC 5907 are spectacular. Magnificent loops of stellar

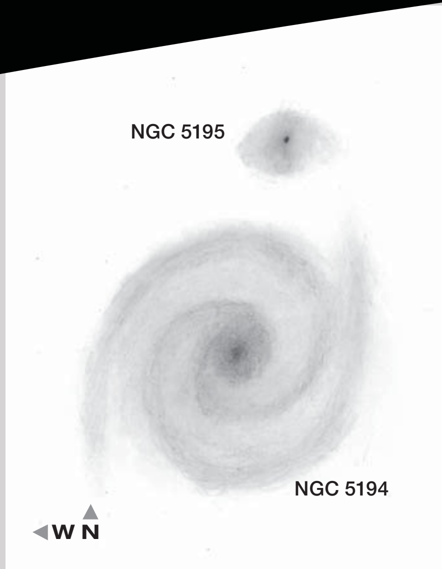




▲ *Top:* Increase the magnification to reveal more of M81's structure. A brighter core is readily apparent, but the delicate spiral arms take more study. This sketch shows the author's view of M81 at 164×. All sketches shown here were made with a 130-mm refractor. *Middle:* At 164×, M82's mottled appearance becomes more visible. Look for the dark dust lanes interrupting its brighter areas, particularly on the galaxy's south edge. *Bottom:* Use a wide-angle eyepiece and lower magnifications (the scene here was captured at 102×) to keep the trio of M65, M66, and NGC 3628 in the same field of view.

SUE FRENCH (3)



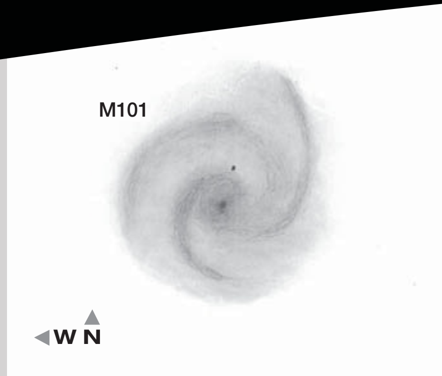


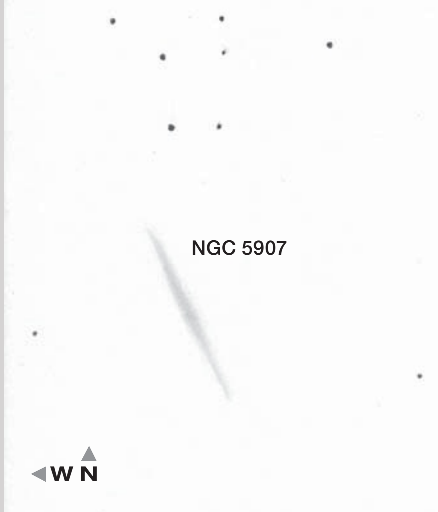
▲ *Left:* Together, NGC 5194 and NGC 5195 form M51. The spiral galaxy NGC 5194 was discovered in 1773 by Charles Messier; Pierre Méchain discovered the smaller NGC 5195 in 1781. In 1845, William Parsons, 3rd Earl of Rosse, revealed M51's spiral structure with his 71-inch reflecting telescope. *Right:* Look for bright cores at the center of NGC 5194 and NGC 5195. The sketch here shows a view of the pair at 164×. Seek out more aperture and magnification to study NGC 5194's elegant arms.

streams enwrap the galaxy, like a still shot of a pirouetting dancer twirling long, gossamer scarves around her svelte form. There are two schools of thought on the origin of these cosmic streams. Some research suggests that they arise from a low-mass, orbiting companion progressively torn asunder and drawn thin by the tidal forces of NGC 5907. Other findings indicate they may be the fossil signatures of an ancient merger of two comparatively large galaxies, the smaller one at least one-eighth the mass of the other.

On star-filled, transparent nights, invest some time exploring these wonderful galaxies to see what features you can elicit from their milky glow. The more you familiarize yourself with them, the more these distant friends will reveal to you.

■ Contributing Editor **SUE FRENCH** loves the challenge of hunting down details in complex galaxies no matter what scope she's using.





▲ *Top:* This sketch shows the center of M101 at 164×. This galaxy can be difficult to pick up due to its low surface brightness, but once located, it takes magnification well. M101's arms spark with star-forming regions. Steady skies and patience will help you trace these stellar knots. *Bottom:* NGC 5907 is a sharp slice of light in Draco. From Earth, we're looking at the spiral galaxy edge-on. Though there's no apparent central bulge, look for a brightening toward the galaxy's center. The author sketched this view at 102×.

Small-Scope Galaxies

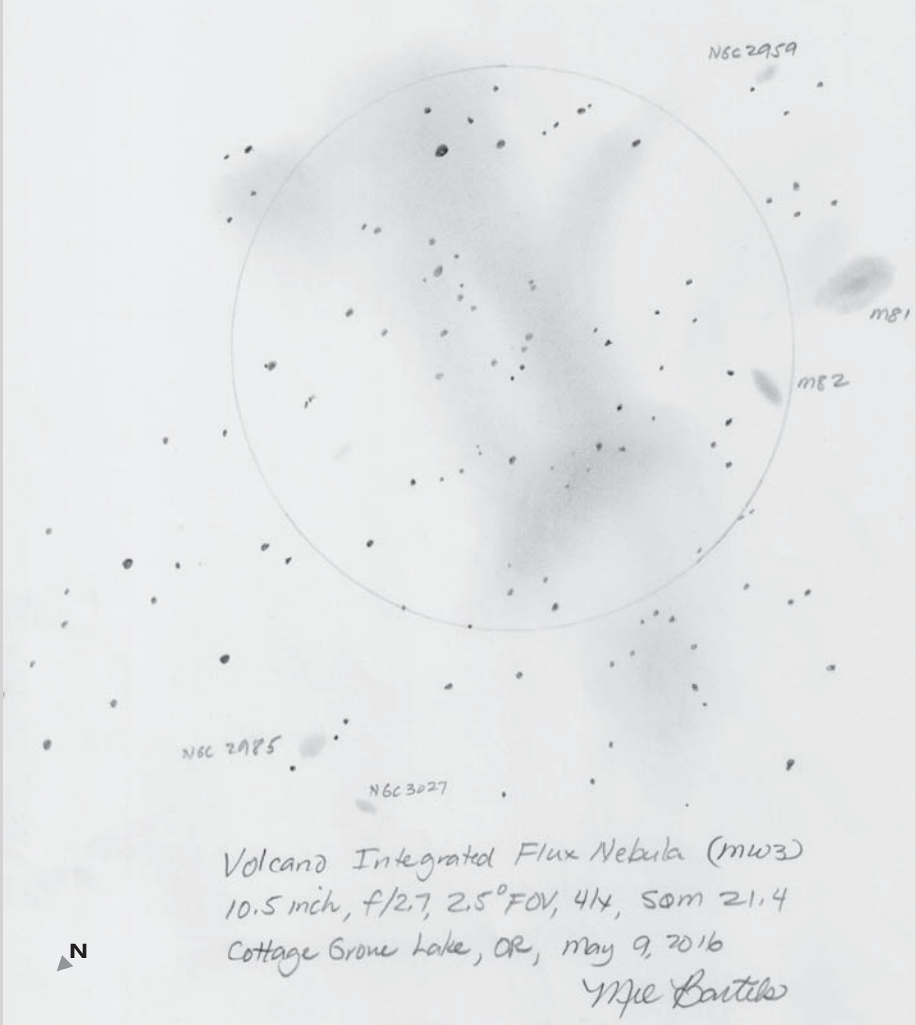
Object	Type	Dist. (Ml-y)	Mag(v)	Size/Sep	RA	Dec.
Messier 81	Spiral	12	6.9	26.9′ × 14.1′	9^h 55.6^m	+69° 04′
Messier 82	Non-Magellanic irregular	13	8.4	11.2′ × 4.3′	9^h 55.9^m	+69° 41′
Messier 65	Weakly barred spiral	31	9.3	9.8′ × 2.9′	11^h 18.9^m	+13° 06′
Messier 66	Weakly barred spiral	31	8.9	9.1′ × 4.2′	11^h 20.2^m	+13° 00′
NGC 3628	Peculiar spiral	31	9.5	14.8′ × 3.0′	11^h 20.3^m	+13° 35′
NGC 5194	Peculiar spiral	24	8.4	11.2′ × 6.9′	13^h 29.9^m	+47° 12′
NGC 5195	Non-Magellanic irregular	24	9.6	5.8′ × 4.6′	13^h 30.0^m	+47° 16′
Messier 101	Weakly barred spiral	22	7.9	28.8′ × 26.9′	14^h 03.2^m	+54° 21′
NGC 5907	Spiral	47	10.3	12.8′ × 1.4′	15^h 15.9^m	+56° 20′

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.

M51 IMAGE: STOCKTREK IMAGES / GETTY IMAGES; SKETCHES: SUE FRENCH (3)

Shimmering Clouds

Galactic cirrus is challenging to observe, but follow the author's advice and treat yourself to a special experience.



It's a funny position to be in, that of observing a galaxy that I've seen countless times and yet seeing it for the first time in a new light. With apologies to Arthur Schopenhauer, I like to think "the task is not to see what has never been seen before, it's instead to think what nobody has yet thought about that which everyone sees."

After observing many extraordinarily faint objects with my new 13-inch f/3.0 high-*etendue* richest-field telescope, under the stars one gloriously clear and transparent night I thought to "go for broke" and try observing the *galactic cirrus* near M81 and M82. To my astonishment, upon centering the galaxies, I could detect faint nebulosity crisscrossing the field of view. It was an extraordinary moment — like stepping through a door into a new universe of observing possibilities. Shivering with excitement, I began searching for other signs of galactic cirrus.

Galactic cirrus lives far above and below the galactic plane. Shining with the reflected light of countless millions of stars, the cirrus forms ghostly shimmering arcs across the sky.

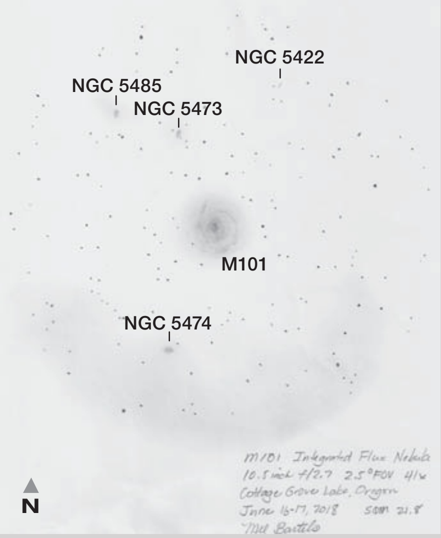
From Arndt Lattusek's research (see *S&T:* Apr. 2017, p. 30 for references), we know the scant and forgotten history of galactic cirrus observations. In the late 1700s William Herschel described 52 areas where he thought the sky "floor" was brighter than the adjoining areas. Austrian-born Father Johann Hagen, first Jesuit director of the Vatican Observatory in the 1920s, observed galactic cirrus but with many false-positive sightings. The great French astronomer and musician Marcel de Kérolyr not only observed but also photographed galactic cirrus in the 1930s. Baron Renaud de Terwangne, an accomplished double star, lunar, and planetary observer (his planetary sketches are quite beautiful), began observing extremely faint nebulous regions in 1929. He later published a map that illustrated his astonishing observations showing that galactic cirrus forms streamers perpendicular to the galactic plane.

Observing Notes

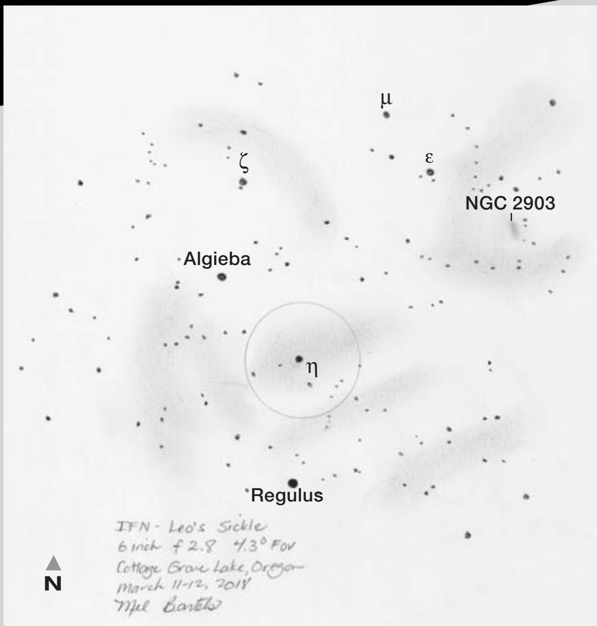
Serendipitously, the brightest galactic cirrus shine at 24.5 mag/arcsec^2 according to Allan Sandage (see his *Astronomical Journal* paper from 1976), which under very dark skies that glow at 21.5 mag/arcsec^2 yields a contrast of 5–6% to the human eye (as calculated by [object + sky background] / object background). I've discovered that I can observe as low

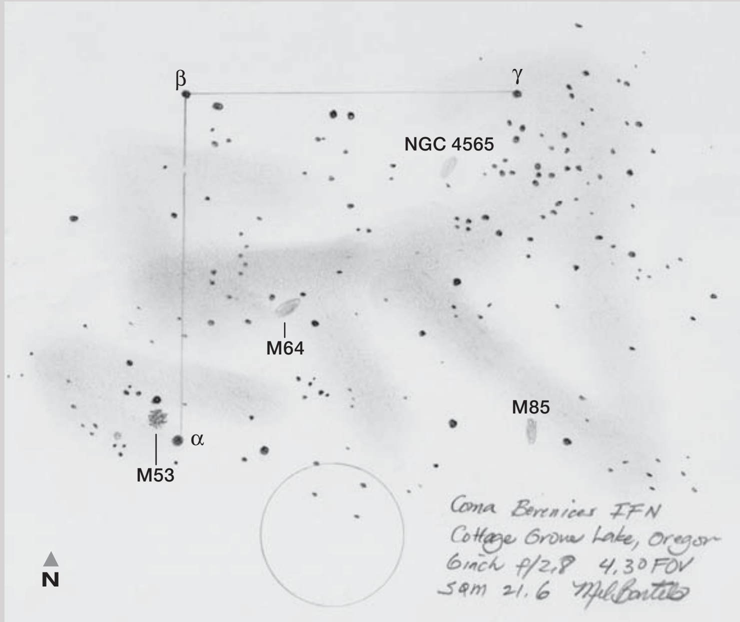
▲ **FIRST GLIMPSE** It was the author's initial sight of galactic cirrus near M81 and M82 that prompted his search for more. All sketches are from the author's logbook and feature his handwritten notes as well as our labeling.

▼ **WIDE FIELDS** The author finds wide fields of view particularly satisfying when viewing galactic cirrus, as in this sketch of M101, the Pinwheel Galaxy, in Ursa Major.



ALL SKETCHES COURTESY OF THE AUTHOR





▲ *Left:* This sketch of galactic cirrus in the Sickle of Leo is a mosaic of several drawings resulting from several "sweeps" of the telescope across the area. *Right:* This mosaic of the Coma Berenices region features not only galactic cirrus but also the tight globular cluster M53 and several galaxies.

as 2–3% contrast, given good object composition in the field of view.

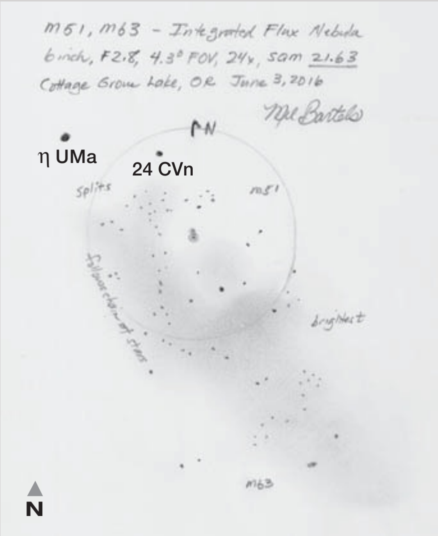
I find that 100° apparent field-of-view eyepieces operated at maximum eye pupil of 5–7 mm are the best for detecting galactic cirrus. Consequently, I use very fast mirrors, f/2.6 to f/3.0, so as to achieve the desired pupil size. The resulting fields of view are eye-opening: 4.2° for the 6-inch f/2.8, 2.4° for the 10.5-inch f/2.7, 1.8° for the 13.2-inch f/3.0, and 1.1° for the 25-inch f/2.6. Not only is the face-on spiral galaxy M101 a wonderful view at low power in the 25-inch, with the spiral arms embedded in the glow of the galaxy, but there's an arc of the Milky Way's galactic cirrus at the edge of the field almost touching NGC 5474. At the same time, the smaller galaxies NGC 5485, NGC 5473, and NGC 5422 are visible. All this makes for an interesting effect, in which the view through the eyepiece appears flat yet my brain is telling me that the cirrus and galaxies form an immensely deep 3D view. I found myself staring at the field for a long time, unable to move to my next object. This leaves a visual memory and emotional astonishment that I can recall by looking at my drawing.

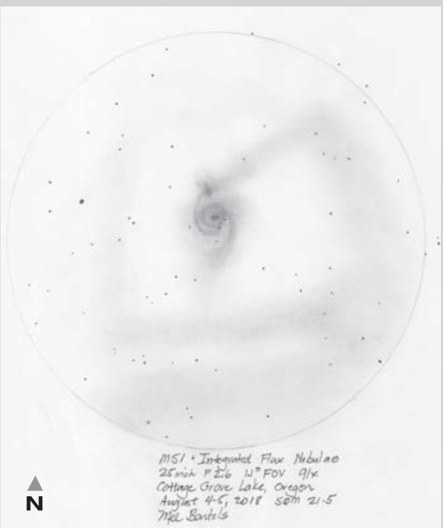
I've begun stitching together fields of view to form sketching mosaics. I'll move the scope back and forth across several fields of view, then pencil in what I see. From the end point, I'll begin another sweep. I'll then sweep all the way back to the very first field of view and repeat the sweeps one after the other until I build up a view up to 100 square degrees. I'll usually go back a second or third night to confirm the sketch as well as tie up loose ends that I failed to knot the first time. The image of galactic cirrus in the Sickle of Leo with the pretty galaxy NGC 2903 above is a mosaic of several drawings, each drawing stretching over multiple fields of view. Luckily it's hard to get lost in Leo's sickle with its prominent guide stars. Another mosaic of the Coma Berenices region not only features the galaxies NGC 4565, M85, and M64, but also the tight globular cluster M53.

Comparing with views through other amateur telescopes, I've found that extraordinarily wide apparent fields of view, dark skies, knowing what to expect at the eyepiece, and enhanced coatings all make a difference. Experience also helps significantly: I see galactic cirrus much more easily now after three years of thorough searching and observing. Filters don't help much — only rarely have I used a narrow bandpass filter to increase contrast in certain views. Surprisingly, aperture doesn't have much impact — if anything, smaller to medium aperture is often better.

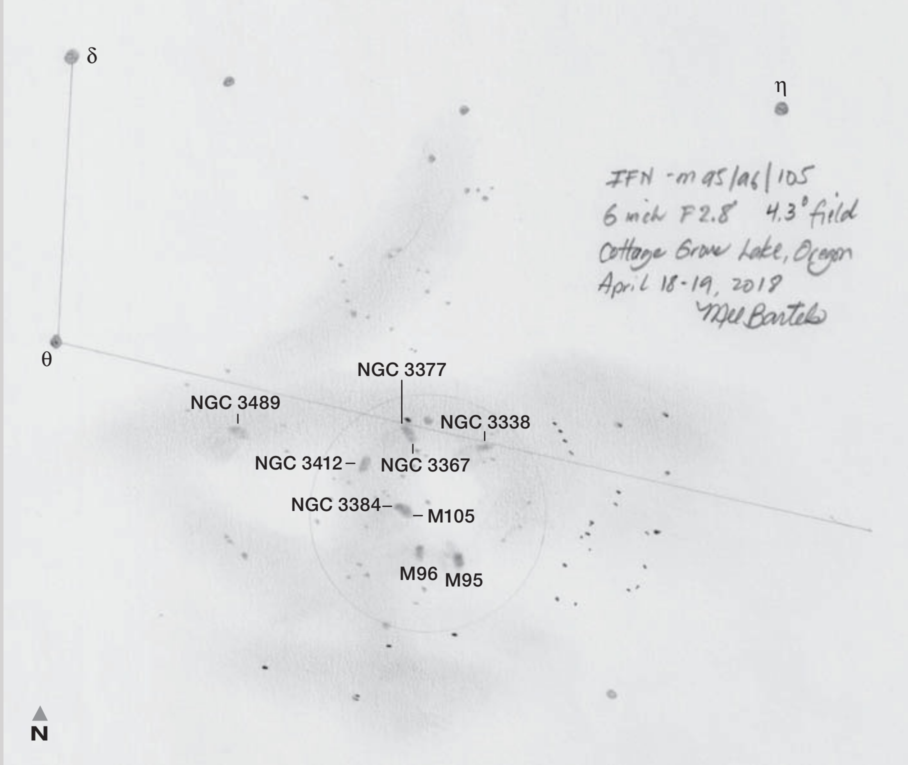
At right is a comparison of M51, the Whirlpool Galaxy, in three telescopes where the aperture doubles, then doubles again: a 6-inch, a 13.2-inch, and a 25-inch. Note that the 6-inch detects a broader area of galactic cirrus but lacks detail near the galaxy itself. The 13.2-inch and 25-inch views are very similar, differing only in image scale, with the galactic cirrus perceived as equally bright in both telescopes. The view in the 6-inch stretches all the way to M63, whereas the view in the 25-inch has enough room for a large M51 and the crisscrossing galactic cirrus of the Milky Way even at low power. All three views through the eyepiece astonish me equally — I cannot pick a favorite.

Dwarf galaxies are a good match for galactic cirrus in that they are approximately the same brightness. Curiously, to my eye there's a difference in hue. Sometimes I'll see the galactic cirrus before I detect the dwarf galaxy — this is the case with the Draco Dwarf Galaxy. In fact, on occasion I'll trace my way to the dwarf galaxy by follow-





▲ **THREE DIFFERENT VIEWS OF THE WHIRLPOOL** These sketches highlight a comparison of M51 in Canes Venatici in order of increasing aperture (top to bottom): 6-inch, 13.2-inch, and 25-inch. The 6-inch telescope provides greater detail of the extent of the galactic cirrus, while the two larger telescopes yield more detail of the galaxy itself.



▲ **FARAWAY GALAXIES** Groups of galaxies, such as this well-known one in Leo, give the author the impression that they're floating in the galactic cirrus — even as he realizes the former are much, much farther away.

ing the galactic cirrus in lieu of star-hopping. The dwarf galaxy Leo I, north of the incredibly bright star Regulus (which needs no star-hopping), is followed farther northward by a faint band of galactic cirrus. The dazzling star, the amorphous dwarf galaxy, and the cirrus form a striking threesome not soon to be forgotten on a cold, clear night.

Particularly impressive are galaxy groupings with galactic cirrus. A pretty field is the M95, M96, and M105 grouping in Leo accompanied by various NGC-level galaxies. Above is a multi-field sketch of the area where I followed the galactic cirrus, stopping at each new field to sketch what I observed. I then drew a large sketch encompassing all the fields of view. The impression in the eyepiece is that the galaxies float in the cirrus, but of course the galaxies are unimaginably more remote.

Final Thoughts

Discovering galactic cirrus next to popular springtime galaxies is a deeply satisfying personal experience. There's no point in shouting — all that does is disturb the night creatures. To stand with my feet on our planet Earth peering into the eyepiece in the cold, clear nighttime air and seeing a new band of ghostly cirrus is an emotional experience that welds me to the inconceivably vast galaxy that we live in and to the grander universe writ large. I've shown galactic cirrus to fellow observers at the Oregon Star Party. When they see the cirrus, it's a "There it is!" moment.

Still, it would be helpful to see digital images of many degrees in size imaged in visual wavelengths that reproduce the eyepiece experience. While visual observers can detect galactic cirrus in minutes, the same view takes imagers many hours of accumulated exposure and processing time. Conversely, digital images are full of breathtaking detail that is simply absent from the eyepiece.

■ During the day **MEL BARTELS** manages a software development team. On moonless clear evenings, he scans the skies with handcrafted richest-field telescopes. Visit Mel's homepage to read more about his observations and telescope making: **bbastrodesigns.com**.

FURTHER READING: See Mel's sketches of the Draco Dwarf Galaxy and Leo I at **https://is.gd/GDApr2019**.

Sony's Mirrorless Marvel

We put a new Sony α7 III mirrorless camera through its paces on deep-sky imaging.

Sony α7 III

U.S. Price: $1,999.99; sony.com

What We Like

Low noise

Bright live-view screen

Low-light 4K movie mode

What We Don't Like

Incompatible with most control software

Sensor mask shadow

Edge glow in long exposures

◄▲ The new Sony α7 III mirrorless camera can do a fine job on wide-field tracker images, like this stack of eight 2-minute exposures at f/2 with the Venus Optics 15-mm, a fast, compact lens made for the Sony E-mount. The Sony camera's tilting screen saves the neck and back when framing and focusing sky shots.

IN THE MID-2000s, digital single-lens-reflex (DSLR) cameras revolutionized all areas of photography, including astrophotography. Today, a new generation of cameras without reflex mirrors lies at the heart of another major change in how we take pictures.

In the past five years, Sony, not a name traditionally associated with cameras, set the bar in "mirrorless" cameras for professional-level photography. Established brands such as Canon and Nikon have only recently entered the mirrorless market but are expected to expand their offerings to the point that the DSLR might soon become a limited-edition camera.

Why Mirrorless?

So what's the attraction? Removing the reflex mirror creates a shorter "flange distance" from the lens mount to the sensor. That, and the lack of a pentaprism for an optical viewfinder, makes for a compact and lighter camera body.

The shallow flange distance also allows manufacturers greater freedom to design fast yet compact lenses that are "native" for the mirrorless cameras. However, by using the right adapter — and there are dozens available — you

ALL PHOTOS BY THE AUTHOR

can also connect DLSR lenses from just about any brand, preserving your investment in existing lenses.

For all types of photography, a major mirrorless advantage is that the preview image you see on the rear LCD screen or in the eye-level electronic viewfinder (EVF) closely matches the image you'll shoot because *it is* the image you're about to shoot. That's because the preview comes directly from the sensor that will take the image. As described below, the Sony I tested can also provide a live simulation of what a long exposure will look like, making it possible to compose night scenes more easily than with a DSLR.

Mirrorless cameras also offer benefits in improved auto focus, in-body image stabilization, high frame rates, and silent shooting — all great for sports, weddings, and other normal fields of photography. But are they better than DSLRs for astrophotography?

To explore the question, I purchased Sony's new and highly acclaimed α7 III, the third generation of their 24-megapixel, entry-level mirrorless camera. With a sensor the size of 35-mm film, the α7 III is a "full frame" mirrorless camera. I tested many key traits, including a few only astrophotographers will ever notice.

▲ The camera accepts E-mount lenses and requires less back-focus on most telescopes, permitting the use of additional accessories in the optical path, such as an off-axis guider.

Noise

While noise performance usually improves with each new generation of cameras, it is the size of the sensor's photosites, or pixels, that determines overall noise levels — the larger the pixels, the lower the noise. The 6,000 × 4,000-pixel sensor of the α7 III has 6-micron-square pixels, comparable to other full-frame cameras in the 24-megapixel class.

As such, I would expect the Sony to exhibit noise levels comparable to its competitors, and that's what I found. I shot nightscape images with 10- to 30-second exposures over a range of typical ISO settings from 800 to 6400, pitting the Sony against a 24-megapixel Nikon D750 and a 26-megapixel Canon 6D MkII. Images from the three cameras looked similar, with the Canon showing slightly more noise due to its smaller 5.7-micron pixels. The same was true when comparing long exposures taken through a telescope.

The Sony offers a back-illuminated (BI) sensor which, in theory, should reduce noise even more. However, at the usual ISO settings we use for astrophotography, I found it did not significantly outperform the four-year-old Nikon D750, which also uses a Sony (though non-BI) sensor.

That said, the α7 III provides noise levels as low as you'll find on today's consumer cameras, with the exception of Sony's own α7s Mark I and II models with their detectors' larger 8.4-micron pixels, which are optimized for low-light videography.

Live View

In astrophotography, focusing is usually done manually, using the camera in Live View mode. You zoom in on a star and focus to make it as small as possible. With DSLRs, framing is usually done by looking through an optical viewfinder. Seeing anything at night can be tough, requiring trial-and-error shots to compose a scene.

Mirrorless cameras don't have optical viewfinders. Instead, the Sony α7 III offers a "Bright Monitoring" mode that electronically boosts the image in its EVF or on the rear screen. This works so well with fast, wide-angle lenses that you can see the Milky Way "live." On a fast telescope, you can even see the brightest deep-sky objects without having to take framing shots!

To access this option, go under Camera Settings 2 > Custom Operation 1 > Custom Key, and select one of the Custom "C" buttons (I put it on C2). Scroll to Display/Auto Review2 > Bright Monitoring, a well-hidden choice that appears only here under the Custom button assignments, not in the main menus. It's worth the hunt, as Sony's Bright Monitoring is far more effective at emulating a long exposure than the "exposure simulation" modes of my Canon and Nikon DSLRs.

▲ This comparison shows the noise levels in a typical moonlit nightscape, all recorded at ISO 3200 with three competitive cameras: the Sony α7 III, Nikon D750, and Canon EOS 6D MkII. The 24-megapixel Sony and Nikon are similar for noise, while the 26-megapixel Canon appears slightly worse due to its sensor's smaller pixels.

Sony α7 III with Bright Monitoring ON | Nikon D750 with Exposure Preview ON | Canon 6D MkII with Exposure Simulation ON

▲ In images of the same scene off their rear LCD screens, Sony's Bright Monitoring mode provides live views of the Milky Way, far exceeding the image detail provided by the Nikon D750 or Canon 6D MkII when in Live View, even with their respective Exposure Preview or Simulation modes turned on.

In addition, the α7 III can magnify a star up to 11.7× for critical focusing, making it easy to nail focus with lenses or when used on a telescope.

Movie Mode

One of the plus points of mirrorless cameras is that they are, by design, also movie cameras, relaying a live movie from the sensor to the preview screens at all times. There's no need to lock up a mirror to enter a special "movie mode."

As with most mirrorless cameras, the α7 III offers UltraHD video (3,820 x 2,160 pixels, often called 4K), recording internally to a fast SD card, or to an external recorder via its HDMI port. Apart from total solar eclipses, you might think 4K movies would have little value for astrophotography. But for me, this capability was one of the main attractions of the α7 III — for aurorae.

The α7 III can shoot 4K movies at 24 frames per second using a down-sampled stream from the full area of the sensor (unlike some cameras that crop the frame by up to 1.7× when shooting 4K). That means I can use the same fast wide-angle lenses I use for still images and not lose any of their wide field of view essential for aurorae.

What's more, the Sony can shoot 4K movies with "dragged" shutter speeds as slow as ¼-second, allowing more exposure time for each movie frame. This makes it possible to shoot real-time movies of aurorae at ISO speeds from 6400 to 25,600.

Even at ISO 25,600 videos look acceptably clean and are much less noisy than what my Canon 6D, 6D MkII, and Nikon D750 can achieve. An example video is on my Vimeo channel at **https://is.gd/aurora_test**.

Battery Life

One drawback of mirrorless cameras had been their short battery life, due to their constant use of power-hungry "live view" at all times. This was needed to feed a preview image from the sensor to either the rear LCD screen or EVF.

In contrast to earlier models of mirrorless cameras that required several batteries to get through a night of shooting, I found the Sony α7 III about as good on battery life as any of my DSLRs. One battery proved sufficient for 2 to 4 hours of time-lapse or deep-sky shooting. However, when a long shoot is underway, turning off the rear screen and EVF as well as WiFi and Bluetooth functions helps minimize power draw.

▲ Sony's superb Bright Monitoring option is extremely well hidden: It can be accessed only by assigning it to one of the camera's physical Custom C buttons using the Custom Key then Display/Auto Review2 menus.

Deep-Sky Imaging

Capturing deep-sky objects through a telescope using exposures of several minutes is the most demanding task we can throw at any camera, DSLR or mirrorless. To use the latter, the first task is to physically attach the camera body to the telescope. Like all Sony mirrorless cameras, the α7 III uses Sony's E-mount standard. While traditional T-rings are available for the E-mount, mating a mirrorless camera body directly to some telescopes might require additional spacers.

The field-flattener lenses required by many telescopes are often designed to provide the best correction using the flange distance of DSLR cameras, which is about 42 mm for Canons. With Sony mirrorless cameras the flange distance is only 18 mm.

For my testing I used a Metabones adapter, one of many available that allows me to attach my Canon lenses to the Sony. It also works to attach the Sony to any of my telescope-to-camera adapters equipped with Canon T-rings, placing the Sony's sensor at the correct distance from the field flattener.

Control Options

Being popular for time-lapse photography, Sony cameras are compatible with many motion-control devices and bulb-ramping intervalometers. However, for deep-sky imaging many imagers like to use a laptop with specialized camera control software to run their DSLRs. Unfortunately, Sony users are out of luck, as none of the popular control programs (*AstroPhotography Tool*, *ImagesPlus*, *MaxIm DL*, *Nebulosity*, or *PRISM*) support Sony cameras.

To run the Sony at the telescope I used a simple $50 Vello intervalometer that connects to the α7 III through its micro USB port to control the shutter. It's what I also use to shoot simple time-lapses with the Sony because, unlike all current Canon and Nikon DSLRs, the α7 III lacks a built-in intervalometer.

File Compatibility

For all testing I set the Sony to shoot in uncompressed RAW mode, producing files 49 megabytes in size. However, the issue with raw files from DSLRs and mirrorless cameras is that no two cameras' files are alike. Software companies update their raw developers several times a year to open and decode files from new cameras.

The mainstream raw developers all opened and decoded the α7 III's ARW raw files fine, with one issue.

▲▶ The Sony mirrorless cameras excel at low-light videography and in formats up to UltraHD or 4K, which the α7 III can shoot at 24 or 30 frames per second and at either 60 or 100 megabits per second. This is a still frame from a 4K aurora movie captured at 24 fps/100 Mbps and at ISO 25,600 using the Venus Optics 15-mm lens at f/2.

Among specialized astronomy programs I could test, *Nebulosity* 4.2 decoded Sony's raw files, but *DeepSky-Stacker* 4.1.1 could not, as it uses the obsolete "dcraw" decoding module. *AstroPixelProcessor* 1.07 can't open Sony ARW files at all. *PixInsight* 1.8.6 did open and decode the α7 III's files fine using the new RAW support module, which replaces the obsolete DSLR_RAW module that shipped with older versions of the program. Make sure the module is replaced when you update the program.

Stars or Noise

Astrophotographers have criticized Sony's mirrorless cameras for a firmware "improvement" the manufacturer introduced in 2017 that eradicated faint stars in raw files. This was an unwanted side effect of noise smoothing applied internally to exposures longer than 4 seconds. Such behavior would be unacceptable for serious astrophotography.

I found the Sony α7 III does not suffer from "star eating." In images taken of the same targets with the Sony and with the Canon 6D MkII and Nikon D750, cameras that have never been accused of eating stars, the Sony showed stars to the same limiting magnitude and just as sharply. The "star eater" effect was simply not an issue. Other artifacts were more serious.

▼ *Left:* Control options for Sony cameras are limited. An external intervalometer such as this Vello unit connects to the camera through its micro USB port (arrowed) to operate just the shutter for time-lapses and deep-sky images with the camera on Bulb mode. *Right:* Due to a mirrorless camera's thinner body, attaching it to a telescope with a field flattener will usually require an additional adapter to supply the correct lens-to-sensor distance. This is a Metabones adapter between the Sony and a Hotech flattener equipped with a Canon T-ring.

▲ In 600% blowups of 8-minute exposures of the Andromeda Galaxy, the Sony α7 III (left) shows just as many stars as does the Canon 6D MkII (right). The α7 III does not suffer from the "star eating" problem that plagued earlier versions of the firmware. No noise reduction or sharpening was applied to the raw images in processing with *Adobe Camera Raw*.

Star Colors

What the Sony does exhibit down at the pixel level are stars that seem overly colorful. In particular, many faint stars look green, but in reality there are no green stars! I also see this effect on some images taken with my Nikon D750, which also uses a Sony sensor, but never on Canon images.

In a Bayer-array sensor used by most consumer cameras, each pixel has either a red, green, or blue filter in front of it, but there are twice as many green-filtered pixels as red or blue ones. So are the green stars an artifact of pixel-level smoothing being applied by the camera? Or is the effect caused by the anti-alias filter in front of the sensor? Or might it be an artifact of the "de-Bayering" of the data from the Sony sensor? The "green star" effect is present whether or not I used Long Exposure Noise Reduction, but it does vary depending on the software used, suggesting it is a de-Bayering effect.

For example, I see it in when opening the Sony's raw files with *Adobe Camera Raw*, *Affinity Photo*, *Capture One 11*, *DxO PhotoLab 2*, and even Sony's own *Image Edit* raw developer software.

The open source *Raw Therapee* software, which offers a choice of de-Bayering routines, also shows green and overly colorful stars with most of its choices, but not all. Using the IGV or LMMSE options recommended for high-ISO images produces more neutral stars but also tends to wipe out wanted star colors. The same was true of *ON1 PhotoRaw 2019*, a new program vying to replace Adobe's Creative Cloud suite.

The new RAW module in *PixInsight* 1.8.6 worked well, with its default VNG de-Bayer routine producing neutral star colors and no strange pixel-level artifacts.

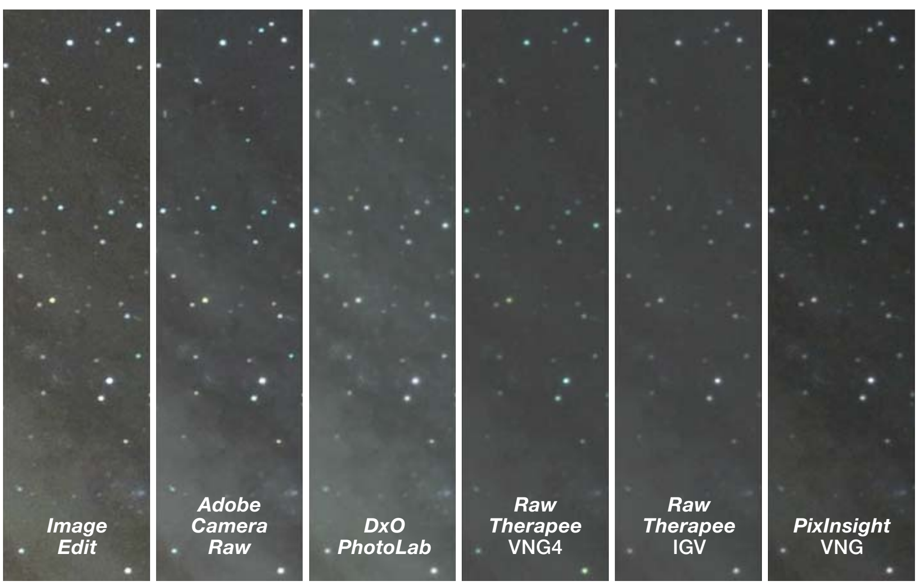
Long Exposure Noise Reduction

Unlike CCD cameras, DSLRs and mirrorless cameras are not temperature-regulated. As such, for the most accurate subtraction of dark frames I prefer to use the camera's Long Exposure Noise Reduction (LENR) option, which forces the camera to take and internally subtract a dark frame for each light frame taken.

Sony's LENR worked well, eliminating most of the hot pixels from thermal noise, but not all. On warm nights, Sony's routine still left some hot pixels. Most noticeable in the shadows of nightscape images, these required manual cleanup.

Red Sensitivity

The Sony α7 III I tested was an off-the-shelf stock unit. As such, sensitivity to the deep-red hydrogen-alpha wavelength, required for picking up faint nebulosity, was no better, but no worse, than my stock Canon and Nikon DSLRs.



◀ Depending on the software used to develop Sony's RAW files, stars tend to show overly abundant colors. This compares 500% blowups of M31 with, from left to right, Sony's own *Image Edit*, *Adobe Camera Raw*, *DxO PhotoLab*, *Raw Therapee* with its VNG4 (colorful) and IGV (neutral) de-Bayer routines, and with VNG mode in *PixInsight*.

If you wish to go after nebulae, consider getting your camera modified by having its infrared cutoff filter replaced with one that lets through more of the deep red wavelengths. Note, though, that Spencer's Camera (**spencerscamera.com**), which modifies many models of cameras, specifically warns against modifying the α7 III due to the light-leak issue discussed next.

▲ Same-night shots of IC 1396 in Cepheus, here with minimal processing, show the Sony α7 III nearly identical to a stock Canon 6D MkII for red sensitivity. Neither can match the author's filter-modified Canon 5D MkII for its ability to record Hα nebulosity.

Edge Glow

The most disconcerting trait of the α7 III for deep-sky imaging is the presence of a purple glow along the left edge of the frame. It's always in the same place and of the same shape regardless of whether LENR is used or not. If this was a thermal "amplifier glow" from warm electronics, subtracting a dark frame should eliminate it. It does not.

The purple glow comes from an infrared-emitting sensor near the shutter and is apparent only in multi-minute exposures of deep-sky objects. The large degree of contrast enhancement required in deep-sky image processing makes the glow visible. Counteracting it requires painting in masked local adjustments during processing, an awkward workaround.

Sensor Shadowing

With DSLRs the raised mirror can cast a subtle shadow along the bottom edge of the frame, which, like edge glows, becomes visible only under typical deep-sky processing. With no mirror, I would have expected the Sony's image to be free of any such edge shadows, but not so. A metal mask in front of the sensor has two tabs that intrude into the light path, creating two dark bands on either side of the top edge of the frame.

While these shadows can be dealt with using flat fields and other local corrections when processing, with a mirrorless camera we should not have to deal with any vignetting from intrusions around the sensor.

Recommendations

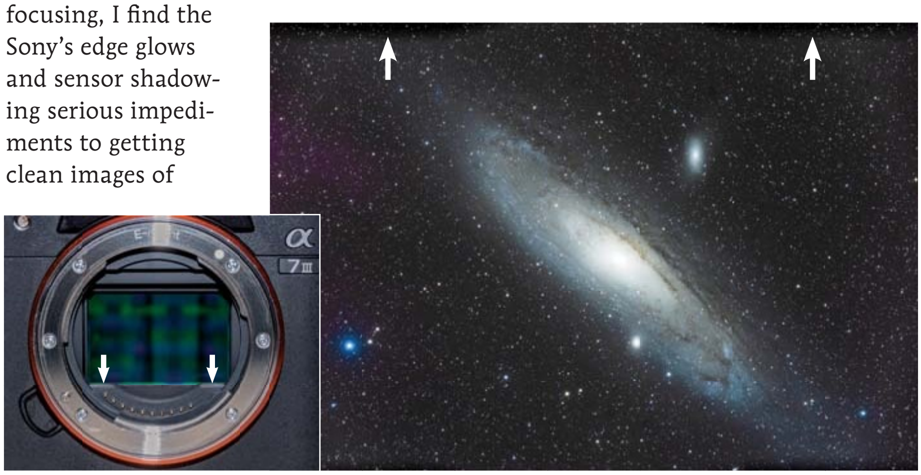
For real-time 4K videos of aurorae, the α7 III is superb. Only Sony's α7s cameras will outperform the α7 III for low-light video work, though at a higher price.

For nightscape still and time-lapse photography, with typical 4- to 40-second exposures, the Sony has become one of my favorite cameras. Its bright live view makes it a joy to frame and focus night scenes. For long-exposure photography with simple sky trackers and camera lenses, the Sony can produce great wide-field images of constellations and the Milky Way. Users needn't fret over stars being "eaten."

However, for the demands of deep sky close-ups through telescopes, the Sony α7 III would not be my first choice. While it offers low noise and easy focusing, I find the Sony's edge glows and sensor shadowing serious impediments to getting clean images of deep-sky targets. DSLRs from Canon and Nikon still do a better job. How their own full-frame mirrorless cameras introduced in late 2018 will perform for deep-sky imaging remains to be seen.

Sony has set a high standard in leading the mirrorless revolution. But for deep-sky astrophotography the Sony α7 III leaves performance shortfalls that competitors can beat in the new and expanding mirrorless market.

■ Contributing Editor **ALAN DYER** has used DSLRs since 2004 with the breakthrough Canon Rebel 300D. Visit his blog at **amazingsky.net**.



▲ This single image, modestly contrast-enhanced, displays the Sony α7 III's two main flaws for deep-sky imaging: the purple edge glow at left from an internal light source, and the dark shadows at top (and also slightly at bottom) caused by vignetting from a mask in front of the sensor.

▲ IMAGING PLANNER

Skyhound, a purveyor of planning software for amateurs, unveils *SkyTools 4 Imaging* (starting at $199.95). The program helps to take the guesswork out of your imaging by calculating the exposure times necessary to adequately expose for a given target using virtually any camera, telescope, and filter combination. *SkyTools 4 Imaging* also helps you maximize your efficiency by informing you when your target is optimally placed in the sky to image. It can also generate plans that can be directly imported to the popular observatory control program *ACP*, and it can also generate plans for iTelescope.net. *SkyTools 4 Imaging* automatically keeps track of your progress on astrophotography projects that span multiple nights, including extensive mosaics.

Skyhound
P.O. Box 1182 Cloudcroft, NM 88317
575-446-1221; skyhound.com

▶ COOLED CMOS

QHYCCD announces a new model in its COLDMOS camera series: The QHY294C ($999) is a 14-bit, back-illuminated CMOS camera for deep-sky astrophotography. The camera is designed around the 4⁄3-format Sony color IMX294 BSI CMOS sensor with a 4,164×2,796-pixel array (11.6 mp) measuring 19.28×12.95 mm with 4.63-micron-square pixels. Its dual-stage thermoelectric cooling is capable of stable temperatures of 35° below ambient, producing low-noise images through its USB 3.0 interface with additional proprietary QHY amplifier glow suppression. The unit is capable of recording 16.5 full-resolution frames per second, and more using on-chip region-of-interest. An internal 256-megabyte DDRIII image buffer ensures no frames are dropped during downloads. Each camera comes with a 1-meter, 12V threaded power cord, a 1.5-m USB 3.0 cable, and a 2-inch nosepiece, plus a CD with camera drivers and control software. Visit the manufacturer's website for additional details and accessories.

QHYCCD
qhyccd.com

▶ BUDGET ED REFRACTOR

Astro-Tech reintroduces a 4-inch doublet in its popular line of ED doublet refractors. The AT102ED ($599) is a 4-inch f/7 refractor that incorporates one element of FK-61 extra-low-dispersion (ED) glass to produce sharp, color-free views for amateurs on a tight budget. The scope includes a dual-speed, 2-inch focuser and 1¼-inch eyepiece adapter, both of which utilizes brass compression rings that won't mar the barrels of your eyepieces or other accessories. All optical surfaces are multicoated to virtually eliminate reflections and provide high-contrast views. Each scope includes a pair of hinged tube rings, an 8-inch Vixen-style dovetail mounting plate, and a fitted lens cap.

Astro-Tech
Available from Astronomics
680 24th Ave. SW, Norman, OK 73069
800-422-7876; astronomics.com

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.*

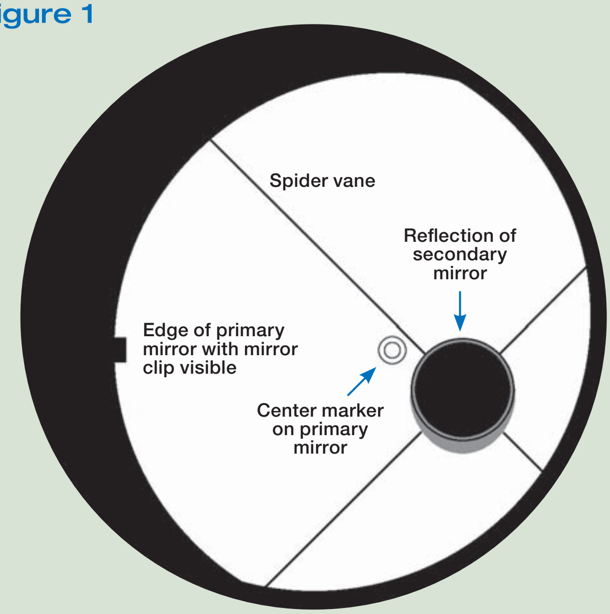
Nurture YOUR NEWT II: Collimation

Aligning your reflector's mirrors — critical to getting the best view — is easier than you think.

In our first installment of this series, we talked about keeping your Newtonian telescope clean and how to wash the primary mirror when it gets dirty. Now let's look at how to collimate it.

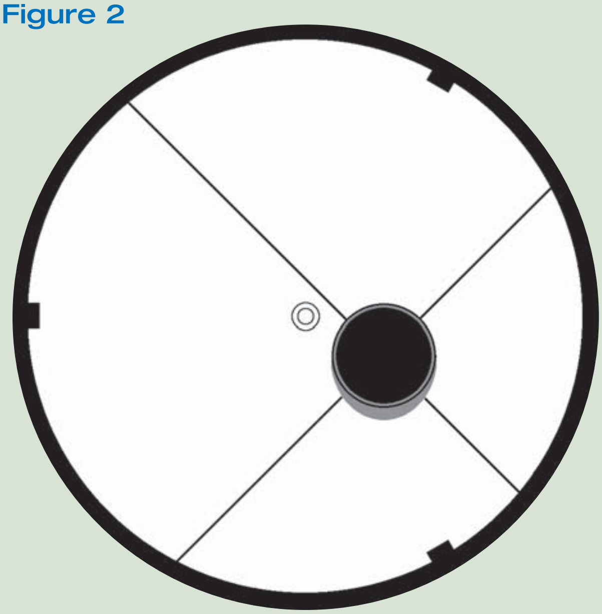
Like mirror washing, collimation is a lot easier than many people think. The Internet is so full of scary advice on collimation that many people think it's as dangerous

Figure 1



▲ **OUT OF WHACK** You'll see something like this when neither the primary nor the secondary mirror is aimed properly. Each illustration depicts the telescope pointing straight up.

Figure 2



▲ **SECONDARY ALIGNED** When the secondary is adjusted properly, the entire primary will be visible within its perimeter. Note that all three mirror clips are equally visible.

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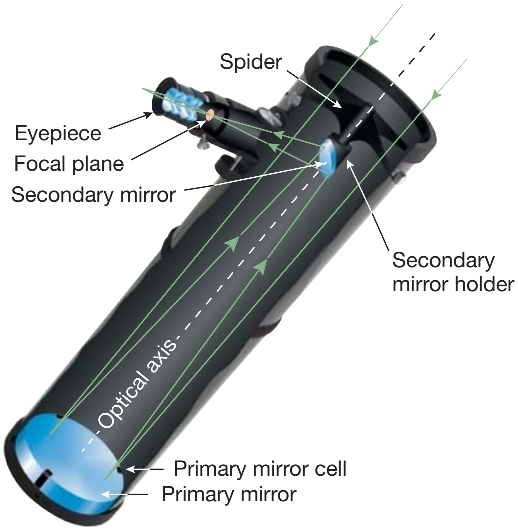


ALIGNMENT ANXIETY One of the most frequently noted disadvantages attributed to the Newtonian reflector is its need for regular collimation of its two mirrors. But this supposed disadvantage can be reduced to a minor task if approached methodically.

as choosing whether to cut the red wire or the green wire when defusing a bomb, but it's really pretty simple. The hardest part is probably learning to say it properly. (It's coll-i-ma-tion, not cul-min-a-tion or coll-im-na-tion.)

Collimation means lining the mirrors up in a straight line. The primary mirror needs to be pointing more or less straight out of the tube, the secondary mirror needs to be more or less centered over the primary, and it needs to bounce incoming light down the center of the focuser's drawtube. I say "more or less" because the primary's aim down the tube isn't all that critical, and the secondary is seldom truly centered. In fact, it's usually deliberately off-center. We'll get to the "why" of that in a minute.

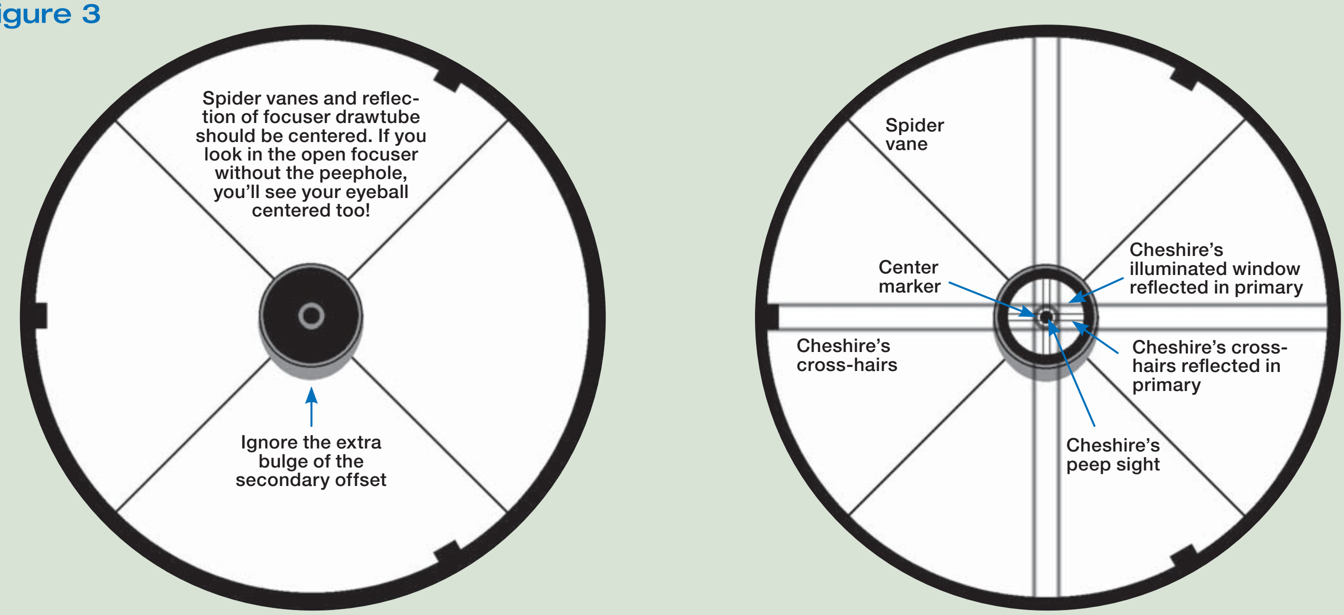
Begin With the Secondary

You start your adjustments at the top of the scope. If you've already looked up collimation instructions online, you may have found some whose first step is "Square the focuser." Scratch that. Unless somebody drop-kicked your scope across the observing field, your focuser is fine. So start by making a peephole about 1/8″ in diameter that goes in the focuser like an eyepiece. A 35-mm film container with the bottom cut off and a hole drilled in the cap works great for this if you can find one. In a pinch, you can tape some paper over the focuser and poke a hole in it. The purpose of the peephole is to force your eye to stay centered over the drawtube.

Check first to see if the secondary is too high or too low in the optical tube. It probably won't be, but it might be if someone fiddled with it. You can use the far end of the focuser's drawtube as a reference. The shiny part of the secondary should look centered within that circle. (You might have to put a piece of white paper behind the secondary and wave a flashlight around to see where the edges of the secondary are.) A *Cheshire eyepiece* (a collimation tool consisting of a sight tube containing a beveled reflective surface and crosshairs) makes this a little easier by constricting the diameter of the reference circle, but you can do fine with just your centered eyeball. This adjustment doesn't need to be exact; just get it close, both vertically and horizontally.

The next step is to align the secondary mirror so you

Figure 3



▲ **IN PERFECT TUNE** *Left:* When both mirrors are aligned properly, everything will be centered except possibly the outline of the secondary mirror. *Right:* A Cheshire eyepiece provides crosshairs and a bright inner reference circle. This view also shows the optics in collimation.

can see the entire primary mirror when you look through the peephole. If you see something like **figure 1**, where the primary mirror looks off-center (don't worry about the reflection of the secondary and spider for now), then you need to adjust the secondary until the primary appears centered. Use the adjustment screws on the secondary mount for motion toward or away from the focuser, and rotate the secondary rather than tilt it for left-right motion. (Tilting it sideways will de-center it in the focuser's drawtube.)

Once the primary looks centered within the secondary, look at the reflection of your secondary, spider, and focuser drawtube. If it looks like **figure 2**, you need to adjust your primary mirror until the reflection looks like **figure 3**. Centering can be estimated much more easily if you mark the exact center of your primary mirror (if it's not already marked by the manufacturer, as some are). A small dot with a Sharpie works well, though a self-adhesive hole reinforcing ring used in 3-ring binders is even better for this. In either case, the center marker will not affect your image when observing at all, since it's in the shadow of the secondary mirror.

Don't be confused by the perimeter of the secondary mirror. That will probably not look centered when everything else is, because your secondary has likely been offset slightly away and downward from the focuser to account for the extra distance to the lower half of the secondary from the focuser. (Objects farther away from your eye look smaller, so most ATMs and some commercial manufacturers put more mirror on the far side to compensate.) So just pay attention to the reflection of the spider and focuser drawtube.

The faster your scope, the more critical the collimation. The "sweet spot" in the field of view gets smaller and smaller with faster primaries.

Once you've aligned the primary, that's it. You're collimated. Lock down the primary with the lock screws if you have them. Just snug them up. Don't tighten hard.

Technological Assist

But what about lasers?! Doesn't everybody need a laser? Or at least a combination Cheshire/sight tube?

Nope. Because you can star test. Once you've gotten the collimation as close as possible by sighting through the empty focuser, take the telescope outside at night and aim it at Polaris or, in the Southern Hemisphere, Sigma Octans (because those stars won't move much while you're performing the test). Put your highest-power eyepiece in the focuser and center your test star in the field of view. Now rack the image out of focus just a little and look at the fuzzy donut of light. If it's round with the shadow of the secondary mirror in the middle, you're done. If it's oval or comet-shaped and the secondary shadow is squished toward one side, move the telescope so the image shifts around in the field of view and note in which direction the image looks

▼ **SECONDARY ADJUSTMENTS** *Left:* The secondary mirror can be tilted and rotated. Some adjusters have three screws, some four (not counting the center bolt). *Right:* The primary mirror adjustment will generally have three screws that pull and three that push. Some may just have three spring-loaded screws.

most round. Leave it there and adjust the primary mirror to bring it back to the center. (It's often best to have a helper with this process, since it's difficult to watch the image and move the mirror at the same time.) You may have to repeat this moving-away-and-recentering several times, but you should eventually be able to get a symmetrical out-of-focus image in the center of the field of view.

To confirm your collimation, bring the image to focus. It should shrink to a sharp spot, with faint hints of diffraction rings around it if the seeing is exceptionally good. (Note that you'll never get a pinpoint star image. The nature of light limits the smallest image your telescope can create, so you'll get what's called an Airy disk — a tiny disk surrounded with faint diffraction rings — and you'll only see that under excellent atmospheric conditions.)

When you get a symmetrical out-of-focus donut and sharp focus, you're done! Enjoy the view through your perfectly aligned telescope.

Oh, okay. You've got a laser and you want to use it (because lasers are cool!). Here's how:

You'll first need a center marker on your primary, and the very center of that marker needs to be open. (That's why a self-adhesive hole reinforcing ring is useful: It has a hole in the middle.)

After you've determined that the secondary is centered in the view of the focuser (because the laser can't tell you that), stick the laser in the focuser and aim its side window toward the primary mirror so you can see the window while turning the collimation screws. Then snug up the clamp just as you would on an eyepiece.

Turn on the laser and look down the front of the telescope tube. Does the laser beam hit the center of the primary's center marker? If not, adjust the secondary until it does. Remember to use the tilt screws only for motion toward and away from the focuser, and rotate the mirror for sideways motion.

Once the laser beam is centered on the primary, look at the side window of the laser collimator. The return beam should go right back into the hole it came out of. If you don't see the bright spot, the beam is either already dead-on or it's so far off that it's not hitting the window. You can wiggle the collimator to see which it is.

If the beam is misaligned, turn the primary mirror's collimation screws to bring it to center, then lock down the primary with the lock screws (if you have them). Then star test as above.

So what about the Cheshires mentioned earlier? They merely help you do the same as the peephole method, by giving you better reference points in the form of crosshairs and an illuminated circle. I highly recommend using a Cheshire (I prefer them to lasers), but it's an enhancement on the peephole method, not a replacement for it.

A couple of notes: The faster your scope, the more critical the collimation. The "sweet spot" in the field of view where you get a perfect out-of-focus donut gets smaller and smaller with faster primaries. If you want good views through the eyepiece, keep fast scopes well collimated. Slower than f/5 or so, you can get away with a lot of slop (comparatively speaking), because the sweet spot will probably not be far from the center of the field even if your collimation is off a little.

▲ **FOLLOW THE DOT** A laser collimator is quick and convenient, but it's not a complete replacement for the eyeball method.

Several months ago a reader asked if the secondary offset I mention above would affect the star test. Wouldn't the secondary shadow at the middle of the light donut be offset a little? And would that offset be enough to throw off the alignment if you centered the secondary shadow? Yes and no. Technically the offset should be visible. Just hold your hand in front of the scope while performing a star test, and you can see that any obstruction will appear offset if that obstruction itself is offset. But a typical secondary offset is on the order of an eighth to a quarter of an inch. On an 8-inch primary, that means it's about 1.5% to 3% of the light donut's diameter. You're unlikely to see that small a deviation by eye.

Like collimation itself, this effect will become more pronounced with faster scopes because the secondary offset is often greater. It's probably never going to be enough to matter, but if so, the solution is simple: Cut out a circle of paper a little larger than your secondary and set that on top of the spider, making sure it's perfectly centered. As long as the paper's diameter is large enough to completely mask the secondary, the light donut will be symmetrical when the scope is collimated.

If you followed the procedure in the previous article in this series, you now have a clean and collimated telescope. There are as many nuances to the procedures I set forth as there are amateur astronomers. There are other methods I haven't even mentioned. (Google "collodion mirror cleaning" for a thrill.) But the methods I've described will serve you well and will keep your Newtonian telescope functioning like new.

■ Contributing Editor **JERRY OLTION** star tests every time he goes out, but that's because he's, shall we say, fussy.

Frank’s Four-Mirror Binoscopes

Tertiaries? Who needs tertiaries?

Frank shows off “Popeye” at the Oregon Star Party telescope walkabout.

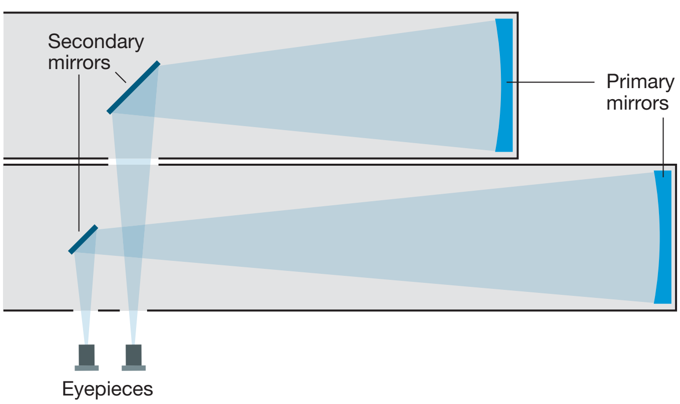
IT’S COMMON KNOWLEDGE in the ATM world that a reflecting binocular telescope requires six mirrors. You need the primaries to gather light and bring it to a focus, you need secondaries to bounce that light off to the side, and you need tertiaries to make the two light cones parallel again and aim them into your eyes.

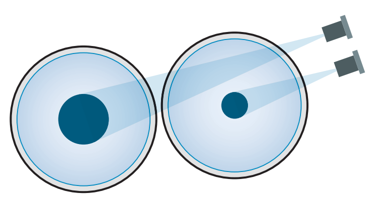
Like most common knowledge, that’s not necessarily so. There’s a way to make a binocular scope with just four mirrors, and Oregon ATM Frank Szczepanski has become a master at it.

The idea has been around a while — the first mention I can find of it is in Albert G. Ingalls’s 1932 book *Amateur Telescope Making* — but for some reason the idea has never really caught on. It should have, though, because the design is simplicity itself: Simply lay two Newtonian scopes side by side and offset them both horizontally and vertically so the light path of one crosses through the light path of the other. When the scopes are oriented properly, their light cones shine directly into an observer’s eyes without any further ado.

It’s that “oriented properly” part that probably scares off a lot of people, but compared to collimating six mirrors on a more traditional binocular scope, it’s not even in the same league.

There are a couple of ways to do it: You can strap two separate OTAs side by side, or you can build both OTAs into a single framework. Frank has gone with the second method.





◀▼ The light cone from the far OTA crosses through the near one, eliminating the need for tertiary mirrors.

One of the first things you notice when you look down the front of one of Frank’s binoscopes is that the secondary mirrors are different sizes. The one in the OTA that’s farther from the eyepiece must be larger than the nearer one, since it’s intercepting the light cone several inches more distant from the eyepiece. That creates a greater obstruction, but the effect is barely noticeable to the eye.

The longer distance between eyepiece and secondary on the more distant OTA means that the primary must be mounted farther forward. Frank puts each primary on its own bulkhead. His scopes are designed to come apart for transport, so there are four bulkheads, all cut and drilled as a single sandwich so everything is perfectly aligned. By doing that and being very careful about centering each optical element, Frank doesn’t need any fancy mounting for the primaries. They have the traditional tilt capability for collimation; no side-to-side adjustments are necessary. To fine-adjust image merging, he tilts just one of the primaries with extended collimation screws that he can reach from the eyepiece.

People’s eyes vary in separation. To adjust the interpupillary distance, Frank mounts the secondary mirror of the nearer OTA on a sliding plate that also contains the focuser. The entire works slides up and down the tube, moving the left eyepiece closer to or away from the right one. Once the correct spacing is achieved, the left eyepiece is refocused. Frank’s latest binoscope, a 10-inch f/5, uses 2″ reverse-Crayford focusers, but other designs simply use snug tubes, and you slide the eyepieces

STAR PARTY: JERRY OLTION; ILLUSTRATION: GREGG DINDERMAN / S&T

themselves in and out for focus.

Baffling between the secondary mirrors is important. If either eyepiece can see the wrong secondary, then it will present ghost images. Frank is careful to limit the light paths so each eyepiece can only see the secondary it's supposed to.

One of Frank's more unusual designs is the scope he calls "Popeye," which uses mirrors of different diameter. He had a 10″ f/7 mirror and a 12.5″ f/6 whose focal lengths were within about 3″ of each other, close enough to use in a binoscope. So he put the larger mirror on the far side, where its extra diameter would compensate for the larger secondary, and it worked beautifully. He didn't bother with a full secondary cage, opting to run the edge of a rectangular cage right through the light path and mounting the secondary on that. I have viewed through Popeye many times and can attest that it works like a charm.

▲ Frank's 10″ binoscope is a hit with his granddaughters . . . and with everyone else who looks through it.

FRANK SZCZEPANSKI

Indeed, all of Frank's binocular scopes (he's done four now) offer superb views, and all with just four mirrors each. As Frank says, "It often takes a little tweaking to merge the images, but when they do, something magical happens and the view just looks more real and three dimensional." And that, dear reader, is why we binocular nuts go to the trouble. You could, too, without even needing tertiary mirrors.

For more information, contact Frank Szczepanski at **5151frszcz@gmail.com**.

■ Contributing Editor **JERRY OLTION** is an avowed binocular nut, and it's all Frank's fault. Thank you, Frank!

TREASURES OF ORION
Alistair Symon
Colorful nebulosity fills this deep mosaic covering nearly all of Orion, from lesser-known objects such as Sh 2-264 (top) and IC 2118 (bottom right) to Barnard's Loop surrounding the Hunter's belt stars (center) and sword areas in the lower half.
DETAILS: *SBIG STF-8300 CCD camera with Canon 70-mm lens. Mosaic of 4 panels, with exposure time totalling 30 hours through color and hydrogen-alpha filters.*

◁ **SOMBRERO GALAXY**

Kfir Simon

The “unbarred” or lenticular galaxy M104 displays a bright central bulge and a prominent dust lane in mid-sized telescopes. Its common name results from its striking resemblance to the classic Mexican wide-brimmed hat.

DETAILS: *Astrosysteme Austria 16-inch f/8 hypergraph with FLI ProLine PL16803 CCD camera. Total exposure: 4 hours through color filters.*

▽ **GLOWING CURTAINS**

Jamie Cooper

A bright, shimmering aurora display appears over the photographer as seen at Tromvik along the northern coast of Norway on December 5, 2016.

DETAILS: *Canon EOS 5D Mark III DSLR camera with 24-mm f/2 lens. Total exposure: 2 seconds at ISO 5000.*

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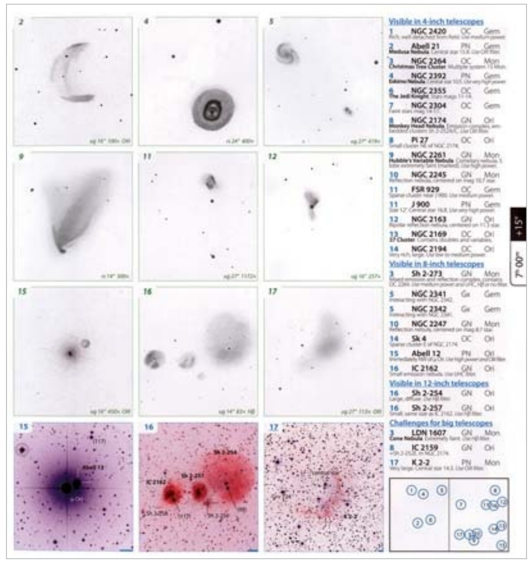
A New Nighttime Companion

INTERSTELLARUM DEEP SKY GUIDE

Ronald Stoyan and Uwe Glahn
Oculum-Verlag GmbH and Cambridge University Press, 2018

Desk Edition, 264 pages, ISBN 978-1108453134, $99.00, spiral bound.
Field Edition, 264 pages, ISBN 978-1108453851, $215.00, spiral bound.



▲ **ASTRO ASPIRATIONS** The *interstellarum Deep Sky Guide* offers detailed sky views through POSS II images. The real stars of the book, however, are Uwe Glahn's deep-sky sketches. Shown here are objects found between right ascension 6^h to 7^h and declination +6° to +24°.

AS A WISE SAGE (or perhaps Alexander Graham Bell) once said, preparation is the key to success. This is as true for observing as any other endeavor. Of course, there are nights when a clear sky coincides with some unexpected free hours, and others when well-conceived plans need to be abandoned due to weather. But I like to set up my telescope with at least some idea of what I'll look at that night. I draw on many references, both digital and hard copy, when I compose my observing lists, so I'm always happy see a new book or celestial atlas made available.

The *interstellarum Deep Sky Guide* by Ronald Stoyan and Uwe Glahn is a useful and welcome addition to my bookshelves. Designed as a companion to the *interstellarum Deep Sky Atlas* (*S&T:* August 2015, p. 57), the *Deep Sky Guide* is a compendium of images, sketches, and short descriptions covering about 2,400 deep-sky objects visible with scopes as small as 4 inches (100 mm). Like the *Deep Sky Atlas*, the *Deep Sky Guide* covers a wide variety of objects, including some truly obscure nebulae, galaxies, and quasars. To give observers an idea of how objects will appear in the eyepiece, the authors have selected more than 1,700 images from the second Palomar Observatory Sky Survey (POSS II). The images are well labeled and act as detailed finder charts. At the eyepiece, a dim red light cancels out most of the red channel data on the page; at the desk, visual observers need to look through the red to concentrate on the blue channel, which provides a closer approximation to an eyepiece view.

One of the most attractive elements of the *Deep Sky Guide* is its inclusion of 800 of the authors' deep-sky sketches. Glahn, who drew most of them, typically produces what I consider to be aspirational work: He shows what we would see if we had the patience to study a single object for several hours under high magnification with a large-aperture scope. Most of his results are out of reach from modest backyard observatories, but they may inspire observers to match his tenacity. An averaging of the authors' impressions and the POSS II images gives a more realistic idea of what small-scope users can expect in the eyepiece. Large-scope owners can embrace the "challenges for big telescopes" listed at the bottom right of each spread.

The field edition of the *Deep Sky Guide* is printed on waterproof paper and bound in a plastic cover. It also comes with a durable slip cover, making the book even sturdier. The soft cover on the desk edition is more fragile, but the paper quality is high enough that it should withstand a bit of dew. Each page holds a great deal of information, with most of the real estate given over to images and sketches, so it can be difficult to read the fine-font object descriptions at the eyepiece. The descriptions are rather short to boot.

The *Deep Sky Guide* functions as a standalone reference book but works best as a companion to the *interstellarum Deep Sky Atlas*. The page-numbering system and object designations are the same in both books (M92 is always called M92, not NGC 6341, and it's on spread 19 in both the *Deep Sky Guide* and *Deep Sky Atlas*). Small diagrams in the *Deep Sky Guide* show the location of an object on the matching spread in the *Deep Sky Atlas*. Even so, I wish more precise right ascension/declination positions had been listed for each object. As long as I had the *Deep Sky Atlas* to hand, it was a small complaint. When I used a different atlas, it became a larger problem. You may want to invest in the *Deep Sky Atlas* after you've looked at the *Deep Sky Guide*.

Amateur astronomers will find the *Deep Sky Guide* to be a useful reference for observing sessions. There's something here for practically any telescope, and even if you just kick back and look at the sketches on a rainy night, that would be time well spent.

■ Associate Editor **S. N. JOHNSON-ROEHR** loves a good reference book.

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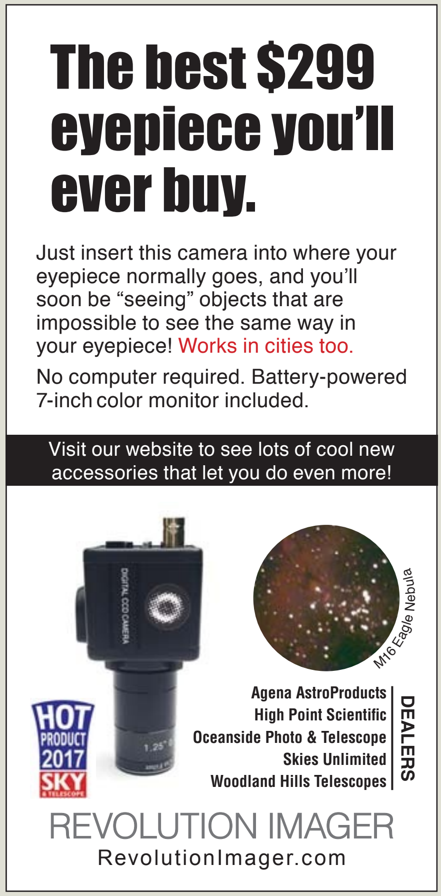

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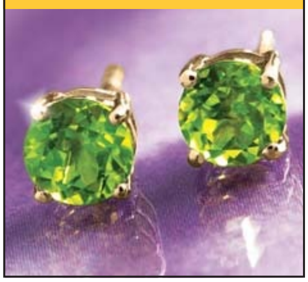

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Planting the Seeds of Wonder

When it comes to successful outreach for a sky event, be careful what you wish for.

AS WEATHER WORRIES FADED at our observing event last July 27th in the heart of Cape Town, a more terrifying threat appeared. How could a handful of our Astronomy Society of Southern Africa, Cape Centre chapter members, alongside a few counterparts from the South African Astronomical Observatory (SAAO), handle the crowds that began pouring in like a zombie apocalypse to witness the total lunar eclipse?

We estimate we had as many as 3,000 visitors that night at the Victoria & Alfred Waterfront, a large mall complex on the harbor. For hours on end, people cued up 50-plus deep at 10 telescopes.

This Frankenstein was of our own making. So what in our outreach efforts worked — and what didn't?

We'd begun by gathering allied organizations. Our club works alongside SAAO, so that was easy. We coordinated event logistics with V&A Waterfront officials but also leveraged their marketing team's talent and media contacts.

We then crafted a one-page, no-hype press release. As we noted, the event's timing was perfect for our target audience. We offered a free, kid-friendly event starting at 6 p.m. on a Friday night. Our chapter's chairperson got the opening quote, followed by the SAAO's Science Engagement Astronomer. The trick was including a closing comment from the venue's marketing communication chief. That turned a passive partner into an active participant. We were able to distribute the release in time for newspapers to pick the story up the weekend prior to the eclipse.

The response was immediate. Local media hyped it as the "'Blood Moon,' Longest in the Century!" Interview requests followed from media across the country, and the BBC World Service took it global. Radio proved crucial. Many of our visitors heard about us from interviews on CapeTalk, the city's dominant news/talk radio station. Social media was valuable, too: Our Facebook event page received some 220,000 pageviews, mostly by women in their 20s and 30s.

Our prep worked so well that we found ourselves completely overwhelmed. The multitude came for the lunar eclipse, but star party staples — Venus, Jupiter, Saturn, and Mars — kept them enthralled at the eyepiece. With all of our team assisting at instruments, we didn't collect or disseminate contact information as well as we might have. Our flyers soon vanished, and we were reduced to telling people how to find us via Google.

Better coordinating between instruments — allocating which was pointed at what planet and the like — would have helped direct guests from line to line. The greatest catastrophe occurred when a lady at my 111-mm APO got lucky and snapped a decent photo of Saturn with her cellphone. Suddenly, everyone tried to duplicate her feat, and the line bogged down. Next time: a single telescope with a smartphone adapter set aside for photography!

In the end, though, we were thrilled. As totality took hold around 9:30 p.m., a unified shout rose spontaneously from the crowd, giving voice to our collective awe. For Aristotle, the quest for knowledge begins with such wonder. Towards 1 a.m., exhausted, we finally packed up, musing about the seeds we'd planted.

■ **CARL LINDEMANN**, an expat American storyteller and community organizer, lives for clear, moonless nights in the Karoo, the desert outside of Cape Town.

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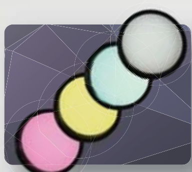

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