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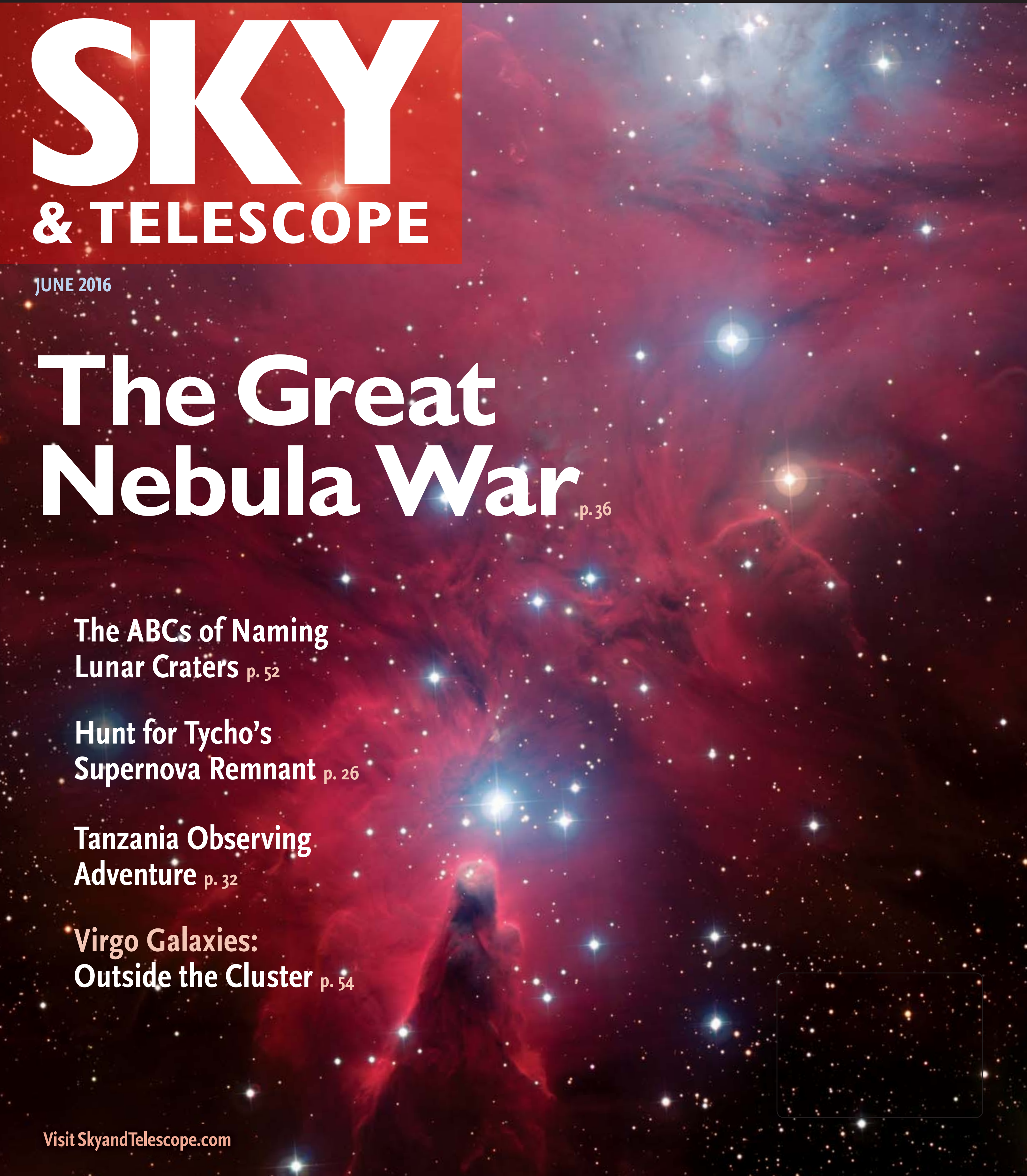
JUNE 2016



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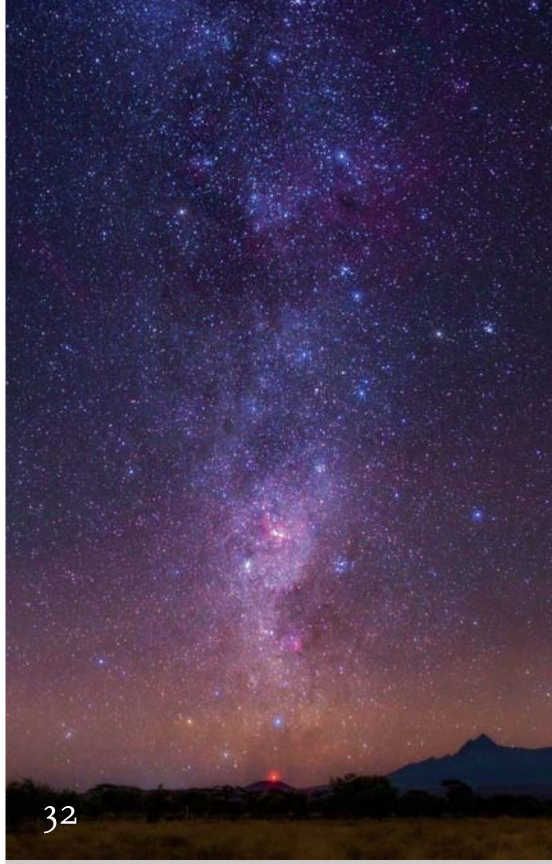
June 2016 VOL. 131, NO. 6

On the cover: This color composite of NGC 2264 spans a region about 30 light-years across.

PHOTO: ESO

ROBERT DICK



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June 2016 Digital Extra

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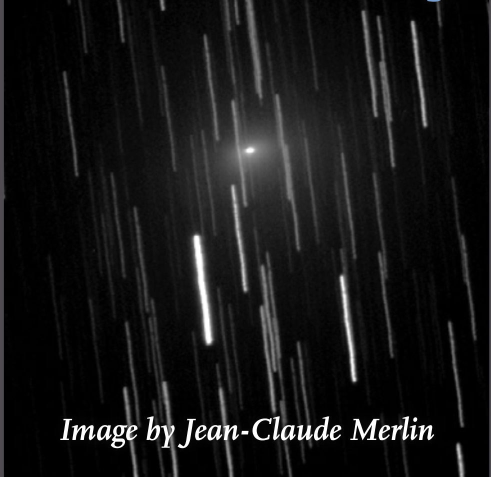
  Go deeper into this month's Going Deep column on this bright nebula.

- **Astro Tourism**
  Want to see the sky — and the world? *Sky & Telescope* offers tours to see Northern Lights, eclipses, and more.

- **WFIRST: The Hubble of the Future**
  Watch a recent Google Hangout with some of the mission's key players.

TOUR THE SKY – ASTRONOMY PODCASTS

Photo Gallery



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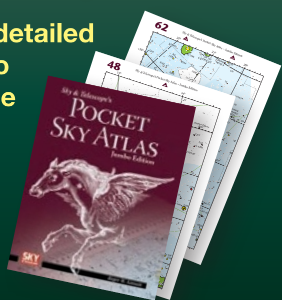

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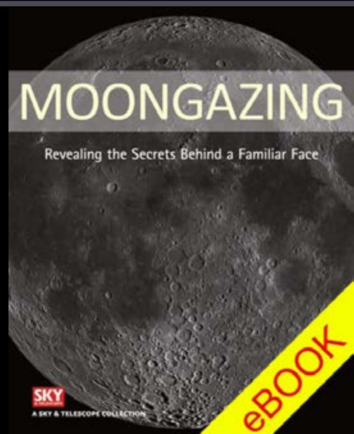

DIGITAL BACK ISSUES:

March, April, and May

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ONLINE PHOTO GALLERY

Muhammad Rayhan's stunning wide-field shot shows the solar eclipse over Palu, Indonesia, on March 9, 2016.

Astro Touring

THERE COMES A TIME on any unforgettable journey to a faraway place when you realize it's all come together somehow in that instant. All the various stimulants that you've been drinking in — cultural and natural, expressible and ineffable — become distilled into a single moment of intoxicating moonshine.

For me, on our *S&T* aurora tour of Iceland last October, that moment didn't occur when I stood between the Eurasian and North American tectonic plates at the very spot where the world's first parliament convened in AD 930, entrancing as that was. Nor did it take place when, after days of overcast, the skies opened up and revealed Iceland's highest peak, Hvannadalshnúkur, a snowy Taj Mahal soaring into the blue.

It wasn't even when the spectacular northern lights we beheld on our second-to-last night reached their fullest extent over our heads. After dinner that evening our group had bussed to a ridge high above the country's famous Blue Lagoon. And there, as if on cue, the aurora borealis had appeared out of nowhere and drew an ever-changing curtain of green-tinted white silk across the heavens.

S&T: SEAN WALKER

Aurora in Iceland, October 2015

No, the instant when everything seemed to coalesce arrived right after that, as we headed back to Reykjavík. It was getting late and we were tired, but we felt electrified, and our guide, Elín, wanted to put the icing on the cake. Einar, our young, bearded driver, happened to be a professional tenor. And as we rolled through the darkness gazing out the windows at the aurora, Einar, whose name derives from the Old Norse words for "bold" and "valor," lustily delivered the Icelandic national anthem.

What was that choice point for Nick Howes in Tanzania (see page 32)? Was it seeing shadows cast by Jupiter as his group observed with an exceptional limiting magnitude of 6.2? Hearing a Maasai chief, who'd just peered through a solar telescope at prominences on the Sun's limb, soberly state that he would never forget the experience? Or, on their final night of observing, watching a huge fireball course across the sky? You'd have to ask him — and you can, as he's leading another astro trip there later this year.

Whether it's heading to the Far North to witness the aurora or to the American heartland to relish a total solar eclipse — see pages 67 and 72, respectively — *S&T* is delighted to work with our travel partners to offer you astronomy-related adventures. (We're not affiliated with Howes's expedition, just fyi.) Watch for more *S&T* tours in the works for 2017 and beyond.

If you join one of our trips, I can't predict *what* your defining moment will be. But I'll wager you'll have one — and it will be all yours. ✦

Peter

Editor in Chief

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Fond Telescope Memories

Wow, Gary Seronik's "Telescope Making Then and Now" (*S&T:* Jan. 2016, p. 72) brings back memories! I've been a *Sky & Telescope* subscriber since 1959, and back then we created a lot of our own equipment. I got started by constructing a 4¼-inch Newtonian, including grinding my own mirror!

My dad built, with factory parts, an 8-inch Newtonian. (Considering he was the president of a manufacturing company, he was quite mechanically skilled.) He bought the 1/20-wave primary and secondary mirrors from Cave Optical, along with the tube, spider, and mirror mounts. The German equatorial mount was from Magnusson.

I learned and really enjoyed the many hours of helping him lay out a to-scale diagram of the optical path and, later, properly drilling the holes for the mounts and finder scope. I spent several years hauling that telescope outside to three concrete pads I'd dug. Then in 1961 he built a 10-by-10-foot observatory with a bed, desk, and roll-off roof. I even had a darkroom in the basement for developing my pictures of the Moon.

A few years later we built a 16-inch f/16 Cassegrain. He, along with his toolmaker at work, built a skeleton tube out of angle iron (bent into circles) and All Thread rods. Then we made a fork mounting out of channel iron with a 2-inch equatorial shaft inserted into a part scavenged from an injection-molding machine. He managed to obtain the mirrors from John Hindle (son of John H. Hindle) in England. All this was mounted to a 12-by-12-inch concrete column that extended 8 feet high and 4 feet into the ground!

Ash Dome was just 15 miles down the road, and we paid a visit. But rather than buy a ready-made dome, my dad bought a silo, which Ash Dome also sold. We erected it, cut out a 30-inch slot, and made a pair of Palomar-type shutters. That scope never had the use it deserved — by then high-school studies and girls took up much of my time! Sadly, there was no room for it at my home when I got married. I still have the optics — but just for nostalgia.

Paul Rybak
Topton, North Carolina

Did Cassini See the Great Red Spot?

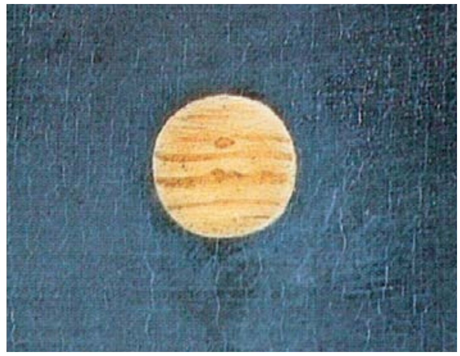
Having written *Sky & Telescope*'s May 1968 cover story, "The Discovery of Jupiter's Red Spot," I was somewhat taken aback by a caption in Amy Simon's article (*S&T:* Mar. 2016, p. 18) that reads, "Historians generally (but not universally) believe [that 17th-century] observers saw something other than the Great Red Spot."

I don't know who these "historians" are, but I made a strong case that the feature seen by Cassini and by his nephew Giacomo Maraldi during 1665 to 1713 was, indeed, the Great Red Spot.

Perhaps the most significant difference between the 17th-century spot and the modern one has been its size. Cassini's spot was apparently 9½° to 13½° across, roughly a third of the GRS's typical width during the 20th century. But, as the main point of Simon's article emphasizes, it has now shrunk to the size of Cassini's feature.

Everything else regarding the ancient and modern spots, such as latitude and cycles of fading and reappearance, is similar. It's been claimed that Cassini's spot had a very different rotation period, but those early measurements were not robust; during 1693 the spot might well have had a period similar to that of the modern Great Red Spot.

Clark R. Chapman
Southwest Research Institute
Boulder, Colorado



VATICAN MUSEUM

Donato Creti's 1711 painting shows a detailed Jupiter and three of its moons looming large in the sky. The oval spot above center (which would be toward south in that era's refracting telescopes) bears some remarkable similarities to the Great Red Spot.

Amy Simon replies: *The size difference is indeed a key factor, but other descriptions I've read have been a bit vague about some of the spot's other aspects as well. However, the exceptionally long gap in credible reports, almost 200 years, is probably the real proof. The GRS was distinct enough in the late 1800s that earlier observers, had they seen it, surely would have reported it. Cassini, Hooke, and likely other contemporaries saw something, but there's no clear evidence it is the same storm we see today.*

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The Inconstant (Carbon) Stars

Alan MacRobert refers to visual estimates of carbon-star brightness as "notoriously unreliable" (*S&T:* Feb. 2016, p. 44). I'd be very interested in any studies that have investigated this claim and, if possible, quantified it. It certainly makes sense, and one could speculate on possible causes. However, a few years ago I found that the color of comparison stars makes no difference to the overall accuracy of visual estimates of Mira-type variables (see **arxiv.org/abs/1203.6394**).

Alan Whiting
Alexandria, Virginia

The "Draw" of Saturn

Thank you, Dean Regas (*S&T:* Feb. 2016, p. 76), for the reminder of my first view of Saturn through my very own "telescope." I had put together a set of lenses and tubing and leaned it over a fence while pointing in the planet's direction. There it was, a round blob with ears, and it was the thrill of my young lifetime. (I later received a Skyscope 3.5-inch Newtonian that resolved the blob to my satisfaction.)

Having been introduced to astronomy by my father at a very young age, I started reading about it as soon as I discovered my local library. So, when my sixth-grade class went to Lick Observatory in June 1946, I was well prepared and dazzled the class and the astronomer with my knowledge. I "showed" them Albireo, the well-known double star in Cygnus, through the 12-inch refractor there. But the trip's high point, without question, was seeing Saturn through Lick's amazing 36-inch refractor.

Bill Pitsker
Petaluma, California

The Case for M103

I second Tom Reiland's suggestion (*S&T:* Feb. 2016, p. 8) that M103 might be NGC 663 and not NGC 581. In Messier's published catalog, this was among the unconfirmed objects for which no position was given except "between Epsilon and Delta [Cassiopeiae]." NGC 663 fits that description slightly better.

In his own copy of the catalog, Messier hand-wrote a position, $1^h\ 20^m$ +61°, which (corrected for precession) is about equidistant from both of those clusters. But it might not be an *observed* position — perhaps he chose the $1^h\ 20^m$ line in his star atlas and followed it up to a declination "between Epsilon and Delta," similar to what I contend he did for his handwritten position of M102.

Many early identifications of Messier objects situated in rich star fields are, I fear, doomed to remain uncertain.

Michael A. Covington
Athens, Georgia

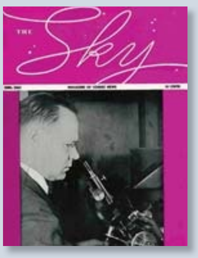
For the Record

✸ *The stars labeled Beta and Zeta Tauri (*S&T*: Jan. 2016, p. 45) are actually Iota Aurigae and Beta Tauri, respectively.*

✸ *In the table of galaxies within the Beehive Cluster (*S&T*: March 2016, p. 59), NGC 2624 is also called MCG +3-22-19.*

75, 50 & 25 Years Ago

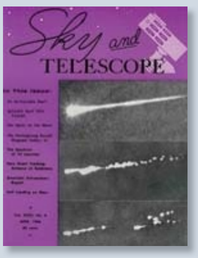
Roger W. Sinnott



June 1941

Coronium "A theory that explains the origin of the mysterious green lines detected in the spectrum of the sun's corona [during total solar eclipses] has been recently offered by Dr. Bengt Edlen, of Sweden. According to this theory these lines, once believed caused by an unknown element, called coronium, are due to the extreme ionization of iron atoms in the sun's corona. Some as yet unknown and powerful excitation from the sun strips them of their normal quota of electrons. In this case, 13 of these electrons are removed."

The true nature of coronium had puzzled solar physicists ever since the total solar eclipse of August 7, 1869, a widely witnessed event that was visible from Alaska to North Carolina. Like helium, it seemed to be a new element unknown on Earth. Edlen's theory finally accounted for the mysterious spectral lines, and later work established extreme coronal temperatures as the excitation cause.

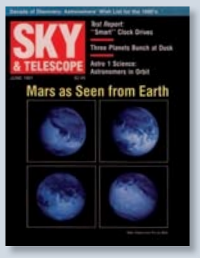


June 1966

Ex-Variable Star? "[An] astonishing report by two Canadian astronomers, Serge Demers and J. D. Fernie of David Dunlap Observatory, [states] that a very well-known Cepheid variable star, RU Camelopardalis, has recently ceased to pulsate and now appears to be practically constant in brightness! . . .

"These observations were carefully made, and no explanation in terms of a misidentified star or instrumental fault is possible. . . . According to the two Canadian astronomers, . . . 'the pulsation has indeed died away. [For the star] to accomplish this in only four years is most remarkable, since simple theory (Eddington, 1926) would indicate a required time-scale of the order of 10^3 to 10^4 years.'"

Soon, however, RU Cam was again pulsating. The star is now classified as a Cepheid of the W Virginis type, with light curves prone to unexpected changes in amplitude or period. These stars are much less luminous than the better-behaved Cepheids that astronomers use as intergalactic distance gauges.



June 1991

Space Junk "Unless spacefaring nations stem the exponential increase in small bits of junk orbiting our planet, some low-Earth orbits (lower than 2,000 kilometers) may become too risky to use in just 10 or 20 years. This is the dire conclusion of a report issued recently by the congressional Office of Technology Assessment (OTA). . . .

"'Cleaning up' space is possible with today's technology but wouldn't be worth the expense. Instead, the best plan is to keep future spacecraft from fragmenting or shedding bits of debris. Shielding spacecraft is also important, but methods need further study."

Today, NASA and the U.S. Department of Defense actively track more than 21,000 objects in orbit. Maneuvering active spacecraft to avoid collisions is a top concern, especially for crewed craft like the International Space Station.

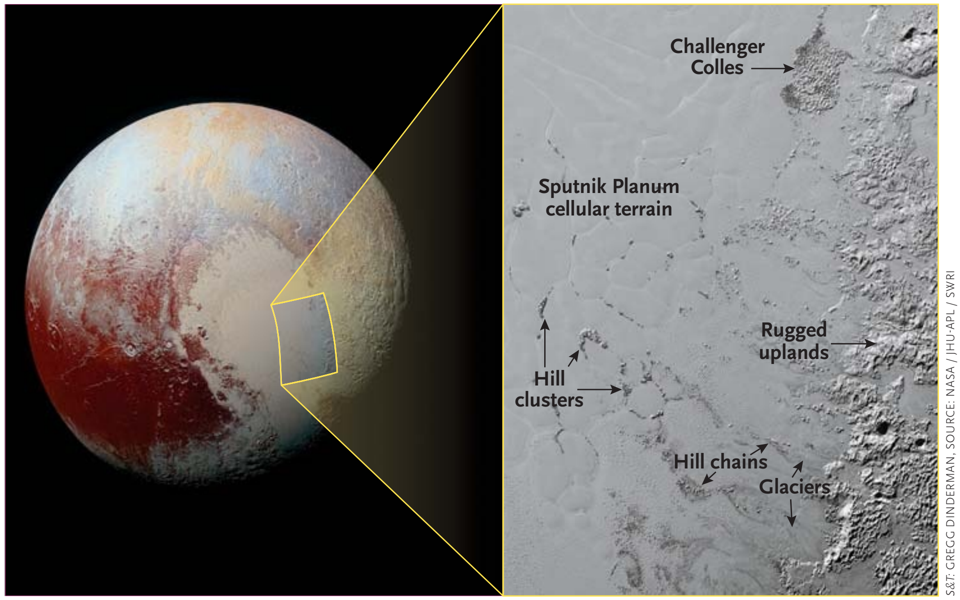
PLUTO | Floating Hills of Nitrogen

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

Within days of New Horizons' historic flyby of Pluto last July 14th, mission scientists released snapshots showing unexpectedly tall mountains partially rimming a vast and very flat plain. The plain, informally named Sputnik Planum, is dominated by frozen molecular nitrogen (N_2) and some frozen carbon monoxide (CO), whereas the surrounding uplands are mostly frozen water.

But recently the team unveiled an image of Sputnik Planum that reveals clusters of hills that stick up through the plain's surface. The plain is made up of large, polygonal slabs, and the hills, which are up to a few kilometers across, appear to be bobbing along in the icy floes and getting trapped where the slabs meet.

Perhaps the mysterious hills are fragments of water ice from the mountains that partially surround Sputnik Planum. Importantly, these water-ice "islands" appear to be analogous to ocean-going icebergs here on Earth — and, as such, they might offer a hint of the depth of Sputnik Planum's frozen nitrogen "sea." So how deep might that be? Assuming that these hills are truly free floating and in what geologists call *isostatic equilibrium*, something like 90% of the mass (and thus volume) of each floating hill lies beneath the surface.



Clusters and chains of hills on Pluto appear to be blocks of water ice "floating" in a higher-density "sea" dominated by frozen nitrogen. The zoom spans about 500 by 340 km (300 by 210 miles).

But these Pluto-bergs are unlikely to be solid throughout. A "reasonable" porosity of 15% would make them significantly more buoyant, explains Jeff Moore (NASA Ames Research Center). Even so, he continues, "We suspect that the N_2 deposit of Sputnik Planum is several kilometers deep — maybe on order 10 km in places."

Interestingly, one large cluster, nicknamed Challenger Colles (honoring those lost aboard the Space Shuttle *Challenger* in 1986; see image above), measures 60 by 35 km (37 by 22 miles). This grouping isn't out in the middle of Sputnik Planum but rather located near its eastern margin, near the peaks of central Tombaugh Regio (another informal name). So perhaps these hills became "beached" once the nitrogen ice got too shallow.

■ **J. KELLY BEATTY**

SUPERNOVAE | Brightest Supernova Baffles Astronomers

The most luminous supernova ever discovered, ASASSN-15lh, challenges popular theories for blazingly bright exploding stars.

The supernova appeared in June 2015 in Southern Hemisphere images taken by the All-Sky Automated Survey for Supernovae (ASAS-SN). Its light traveled for 2.8 billion years to reach Earth, giving it a redshift of 0.2326. Due to its distance, the explosion's glow peaked at only 17th magnitude (*S&T:* Nov. 2015, p. 12).

But its intrinsic luminosity was twice as bright as any supernova yet discovered. Six months later, this single object continued to emit a level of energy that rivaled that of all the stars in the Milky Way combined.

Subo Dong (Peking University, China) and colleagues released an update in the January 15th *Science*. ASASSN-15lh was more than 10 times brighter than Type Ia supernovae (which come from exploding white dwarfs), putting it in the class of so-called *superluminous supernovae* (SLSNe). The explosion appears to be much hotter than normal. Its home is unusual, too: a bright but otherwise unassuming galaxy that forms less than one star per year. Astronomers think SLSNe are the deaths of massive stars, which live fast and die young. Such stars would be rare in ASASSN-15lh's stagnant environment.

Common explanations for SLSNe don't work for ASASSN-15lh. The explosion's spectrum shows no sign of circumstellar material, which would boost the glow when the dying star's outer layers collided violently with it. And the supernova has already emitted more energy than could be provided if the dying star's core became an extremely magnetized, spinning neutron star called a *magnetar*. Astronomers must now explore more exotic options.

■ **MONICA YOUNG**

MILKY WAY | Giant Cloud's Gas Native to Our Galaxy

A massive cloud falling toward our galaxy's disk is likely from the Milky Way itself, not a visitor, a new study shows. This object, called the Smith Cloud, lies 40,000 light-years away and contains 2 million Suns' worth of gas, primarily hydrogen. It's falling toward the galactic disk at nearly 300 km/s (660,000 mph).

The Smith Cloud is one of the best characterized *high-velocity clouds*, speedy wisps that rain down as a light drizzle onto our galaxy. This shower helps fuel star formation (*S&T:* Sept. 2015, p. 16). But despite these clouds' importance, astronomers know a paltry amount about what they're made of and where they come from.

Andrew Fox (Space Telescope Science Institute) and colleagues used the Hubble Space Telescope and the 91-meter (300-foot) Green Bank Telescope to better understand the Smith Cloud's makeup. The astronomers took advantage of three distant *active galactic nuclei* (AGN) that lie behind the cloud from our perspective. With Hubble, the team observed the AGN through the cloud to see how well the gas absorbed certain wavelengths from the accreting black holes' light. Which wavelengths the gas absorbs, and how deeply, reveals how tainted the cloud is by elements heavier than helium, known as *metals* in astrospeak. The researchers found that the Smith Cloud contains about half the concentration of metals that the Sun has.

This artist's conception shows the comet-like Smith Cloud (red) and its current trajectory with respect to the Milky Way's disk. If visible, the cloud would span 30 full Moons.

NASA / ESA

But metals come from stars — they're synthesized in stellar cores or created when stars die — and astronomers don't know of a single star in the Smith Cloud. So it's highly unlikely that this object is a chewed-up dwarf galaxy or a pristine, first-time visitor from intergalactic space.

However, the heavy-element level is a close match for the gas in the Milky Way's own outer disk. The team argues in the January 1st *Astrophysical Journal Letters* that the cloud's gas was either spewed or torn out of our galaxy. And given the cloud's orbit, it either passed through or came from the outer disk about 70 million years ago. So the Milky Way might be feeding on itself.

■ **CAMILLE M. CARLISLE**

IN BRIEF

Booster Impact Site Found on Moon. In December, researchers poring over Lunar Reconnaissance Orbiter images identified the impact site of the Apollo 16 S-IVB stage booster. The booster's impact left a small crater in Mare Insularum 40 by 30 meters (130 by 100 ft) wide, festooned with fresh, brilliant rays, 260 km (160 miles) southwest of the prominent crater Copernicus. It had lain unidentified since the booster crashed into the lunar surface in 1972. The discovery completes the search for the impact sites of Apollo-era rocket boosters. Read more and find out how to scour the lunar surface yourself at http://is.gd/apollo16booster.

■ **DAVID DICKINSON**

Hubble Sheds Light on "Diamond Planet." New observations are helping characterize the atmosphere of an exotic exoplanet. Angelos Tsiaras (University College London) and his team took an infrared spectrum of the super-Earth 55 Cancri e (now called Janssen, *S&T:* Apr. 2016, p. 14). It's the first successful measurement of a super-Earth's atmospheric composition. The team found tantalizing hints of hydrogen cyanide (HCN). This molecule would only dominate in a carbon-rich environment, instead of one based on oxygen-rich silicates as on Earth. That supports researchers' suspicion that this dense world, nicknamed the "diamond planet," contains crystallized carbon in its interior. The team also found no trace of water vapor, which would form easily if oxygen were widespread on this planet, the astronomers report in an upcoming *Astrophysical Journal*.

■ **MONICA YOUNG**

AAS Adopts WorldWide Telescope. The largest national association of astronomers is now the new home of the virtual observatory known as the WorldWide Telescope. WorldWide Telescope is an online portal that theoretically allows access to any observation ever taken, at any wavelength, of a given object or section of sky (*S&T:* Apr. 2015, p. 28). By taking charge, the American Astronomical Society intends to use the portal to make research papers more interactive, with video abstracts and the ability to zoom in or out on and superimpose observations. Team members also hope that, as publishing drives development, the WWT's outreach programs will continue to grow with schools and planetariums.

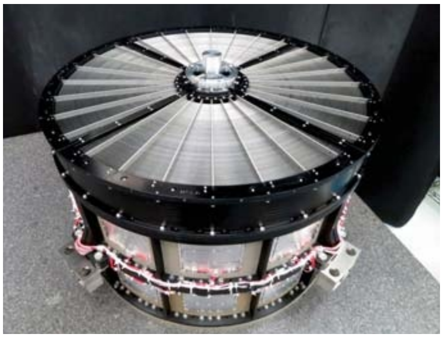
■ **MONICA YOUNG**

Mirror Done for Hubble's Successor. NASA has assembled the primary mirror for the James Webb Space Telescope (JWST), a big step on the way to the telescope's October 2018 launch. The mirror comprises 18 hexagonal segments, each 1.3 m (4.2 ft) across and coated with gold and beryllium. Each weighs 40 kg (88 pounds). Fully assembled, the primary mirror is 6.5 m in diameter, making JWST the largest telescope ever to be fielded in space. The telescope will observe from the long-wavelength end of the visual spectrum into the infrared regime, peering farther back in cosmic time than Hubble can.

■ **DAVID DICKINSON**

MISSIONS | New X-ray Observatory Launches

The Japanese Aerospace Exploration Agency's (JAXA's) new X-ray observatory launched into orbit on February 17th. Formerly known as NEXT (New X-ray Telescope) and then as Astro H, Hitomi (meaning "pupil of the eye"), joins six other X-ray space observatories in studying the hot and violent universe. More than 250 scientists from 61 countries collaborated on it.



NASA / GSFC

X-ray telescopes nest many mirrors inside one another, like the layers of an onion, each one almost parallel to arriving radiation. The mirror assemblies for Hitomi's two Soft X-ray Telescopes (one show above) each contain 203 concentric shells of aluminum segments. The cylinder is 45 centimeters (17.7 inches) across.

The observatory will measure X-ray energies from 300 to 600,000 electron volts (0.3 to 600 keV). For comparison, the Chandra X-ray Observatory covers 0.1 to 10 keV and the Nuclear Spectroscopic Telescope Array (NUSTAR) 3 to 79 keV.

Hitomi sports four X-ray telescopes, two for "soft" (low-energy) photons and two for "hard" (high-energy) ones. These direct X-rays to various imagers and a spectrometer, the latter of which will precisely measure soft X-rays' energies.

"It will be the only X-ray observatory to offer both capabilities [seeing low-energy and high-energy X-rays] at the same time for every observation," says Laura Brenneman (Harvard-Smithsonian Center for Astrophysics). The primary mission is slated for three years.

Circling at an altitude of 575 km in an orbit very similar to Hubble's, the hulking satellite should be visible from latitudes within 40° of the equator.

■ **DAVID DICKINSON**

MISSIONS | WFIRST: Next Decade's Space Telescope

On February 18th and after several years of design studies, NASA announced it is commencing work on the Wide-Field Infrared Survey Telescope (WFIRST), the successor to the Hubble and James Webb space telescopes.

WFIRST will incorporate one of the two 2.4-m mirrors donated to NASA in 2011 by the U.S. National Reconnaissance Office (*S&T*: Sept. 2012, p. 14). The mirror is comparable in size to Hubble's primary but, thanks to its faster focal ratio (f/7.8 compared with Hubble's f/24), will have a field of view 100 times larger in area. However, its resolution will be less sharp than Webb's, and Webb will peer deeper into the universe.

Although the ready-made "spy" mirror speeds development, a significant amount of time and money will still go into instrumentation. The mission is set to launch in the mid-2020s.

Originally conceived as the Joint Dark Energy Mission, WFIRST was the No. 1 mission on the astronomy community's decadal survey wish list. The two main themes it will address are dark energy and exoplanets. Its wide-field imager will search for Type Ia supernovae and gravitationally lensed galaxies in an effort to better understand cosmic expansion, complementing the upcoming European Space Agency's Euclid mission.

On the other hand, the telescope's coronagraphic imager will home in on large, close-orbiting exoplanets to reveal their atmospheres and compositions, complementing space- and ground-based direct-imaging projects.

■ **DAVID DICKINSON**

Learn more about the mission and watch a recent Google Hangout with some of WFIRST's key players: http://is.gd/wfirstago.

IN BRIEF

USPS / ANTONIO ALCALÁ

Solar System Stamps. The U.S. Postal Service has unveiled three sets of new stamps that celebrate the solar system and NASA's exploration thereof. The ones likely to draw most interest involve Pluto and NASA's New Horizons mission (shown above), which supersede a USPS stamp issued in 1991 that labels Pluto as "not yet explored." The Postal Service is also releasing a commemorative sheet of stamps with images of the eight planets from Mercury to Neptune. A third new release involves circular stamps showing a rising full Moon, captured by Florida photographer Beth Swanson, that cost $1.20 each and can be used to mail letters internationally. All three sets should be available by June.

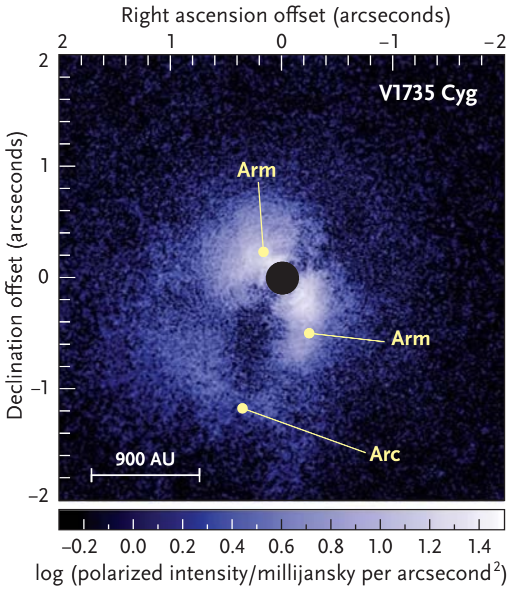
■ **J. KELLY BEATTY**

Repeating Radio Signal from Space. Laura Spitler (Max Planck Institute for Radio Astronomy, Germany) and colleagues report in the March 10th *Nature* their discovery of the first repeating *fast radio burst* (FRB). FRBs are millisecond flashes that seem to come from outside the Milky Way, but astronomers have struggled to explain their origin for nearly a decade. The team detected a powerful burst washing over Earth in November 2012, followed by two more on May 17, 2015, and eight more on June 2, 2015 — all from the same patch of sky and at the same distance. That the blast repeats "tells you without a doubt that this is not a cataclysmic event like a core-collapse supernova or a neutron star–neutron star merger, because that kind of event destroys the object," says coauthor Jason Hessels (Netherlands Institute for Radio Astronomy). Spitler speculates that the repeating FRB might point to a new, energetic class of pulsars. *S&T* will have an in-depth discussion of FRBs in an upcoming issue.

■ **SHANNON HALL**

STELLAR | Stars Form in Turbulent Times

New images of four disks around protostars confirm that stars grow in violent fits and bursts.



This Subaru Telescope image of polarized intensity shows the clumpy disk around V1735 Cygni. The region nearest the star is masked.

HAUYU BAOBAB LIU ET AL. / *SCIENCE ADVANCES* 2016

Stars form when pockets of gas in a cloud collapse under their own gravity into protostars, fed by spinning gaseous disks. Observations have revealed that protostars are far too faint if they're feeding slowly and steadily from these disks. At the same time, a handful of protostars brighten by a hundredfold or more in just a matter of decades before they settle back down. Looking at these clues side by side, astronomers drew the obvious conclusion: accretion is episodic. But they haven't found direct evidence until now.

Hauyu Baobab Liu (Academia Sinica Institute of Astronomy and Astrophysics, Taiwan) and colleagues have now detected pile-ups in the disks around four extremely bright protostars, manifested as clumps, arcs, and streamers. The team reports the near-infrared observations February 5th in *Science Advances*. The researchers are now looking to see whether these structures also appear at other wavelengths.

■ **SHANNON HALL**

STELLAR | Old Stars' Fossil Fields

Astronomers have confirmed that strong magnetic fields are frozen in place deep inside aging stars. Stars create magnetic fields through the convection of hot, ionized gas. *Where* that convection happens depends on how massive the star is: low-mass stars, including the Sun, have convective envelopes around a non-convective core, but stars a little bulkier than the Sun have convective cores.

Recently, Jim Fuller (Caltech) and colleagues found that strong core fields could explain the oddly weak, on-and-off brightening behavior of a sample of red giant stars (*S&T*: Feb. 2016, p. 10). Now, Dennis Stello (University of Sydney), Fuller, and their team have expanded this work to 3,600 red giants observed with the Kepler spacecraft. The astronomers found that here, too, some red giants had "muffled" variations, and how much they were suppressed depended on how massive the star was, with a stronger effect at higher masses. For the heftiest of the sample — 1.6 to 2 solar masses — about half are "depressed," the team reported January 6th at the American Astronomical Society meeting in Kissimmee, Florida, and in the January 21st *Nature*.

The mass boundary between "normal" and depressed red giants is also the transition point from non-convective to convective cores in the giants' progenitors. So astronomers *can* track the strength of a star's internal magnetic field using these brightness patterns.

However, red giants don't have convective cores. But they used to, before their core-hydrogen fusion shut off. Thus the fields muffling the variations are fossils. Magnetic fields are like strings, Fuller says, and they get twisted and tangled by the churning, convective plasma. Once this boiling motion disappears, the field essentially freezes in place. So long as there are no big, bulk motions to disrupt the field, it should just stay put.

■ **CAMILLE M. CARLISLE**

COSMOLOGY | Galaxies Hide Behind the Milky Way

Astronomers have found hundreds of galaxies hidden behind the Milky Way.

Researchers have been mapping out the local cosmic structure for decades, with much success. But there are still some unexplored corners. These generally lie along the *zone of avoidance*, the strip of sky covered by our spiral galaxy's disk.

To peer through the galactic plane, astronomers often observe the 21-cm emission line of neutral hydrogen (HI). This radio wavelength passes through the dusty interstellar muck lying between us and its source. It also reveals the source's distance: astronomers estimate a galaxy's distance based on how fast it's moving away from us, calculated from how much the galaxy's spectral lines have shifted. So any redshift in the 21-cm line's wavelength tells us how far away the HI-filled galaxy is.

An ongoing mapping project, called HIZOA, has surveyed most of the zone of avoidance that's visible from the Northern Hemisphere. Reporting in the March *Astronomical Journal*, Lister Staveley-Smith (University of Western Australia) and colleagues have now released their analysis of the entire Southern Hemisphere ZOA, or HIZOA-S.

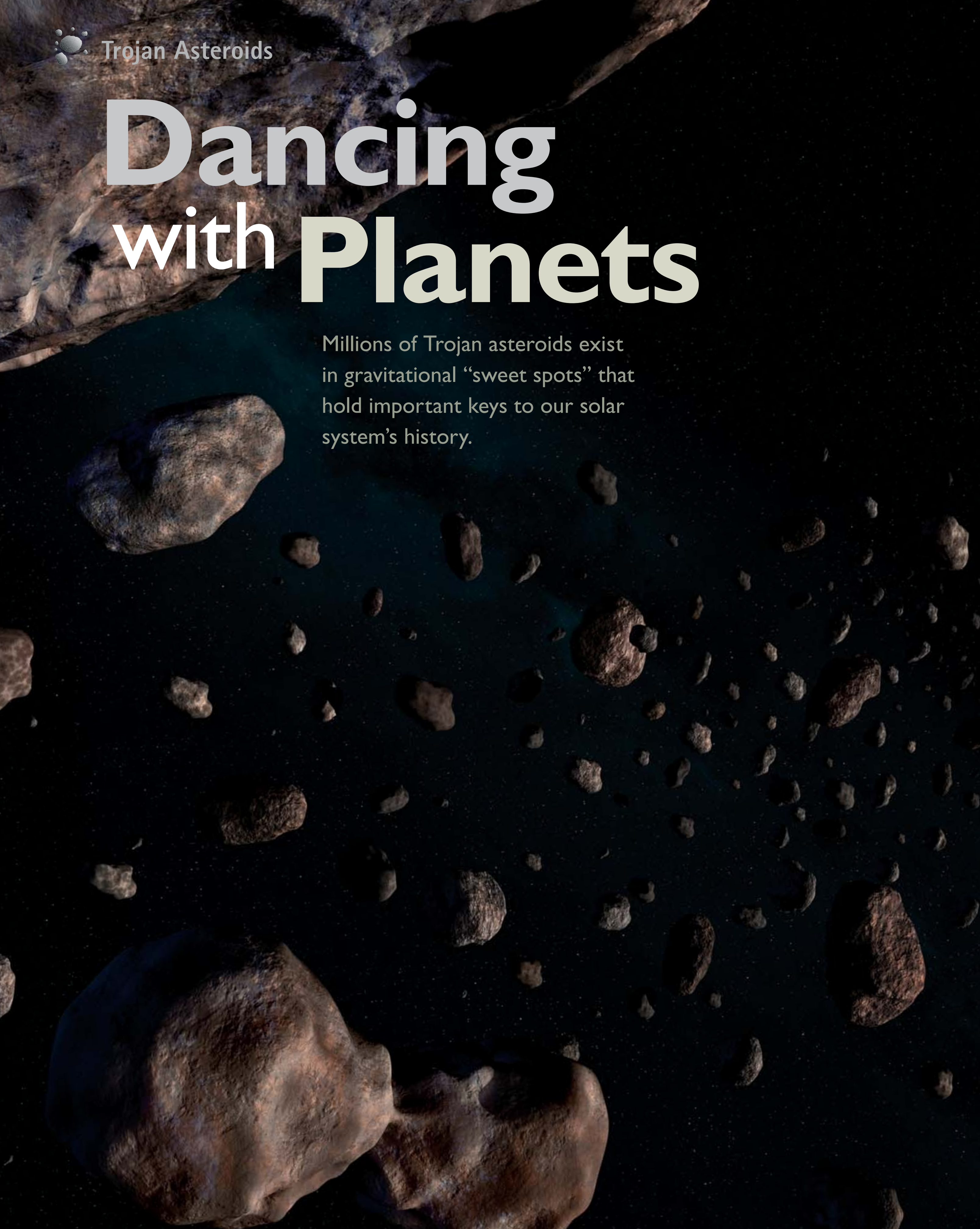
The survey covers more than 1,800 square degrees and probes out to about 250 million light-years, on the scale of our home supercluster, Laniakea (*S&T*: Dec. 2014, p. 16). HIZOA-S found 883 galaxies, one-third of which had never been cataloged, and less than 10% of which had ever had their distances measured. In all, HIZOA has detected 957 galaxies.

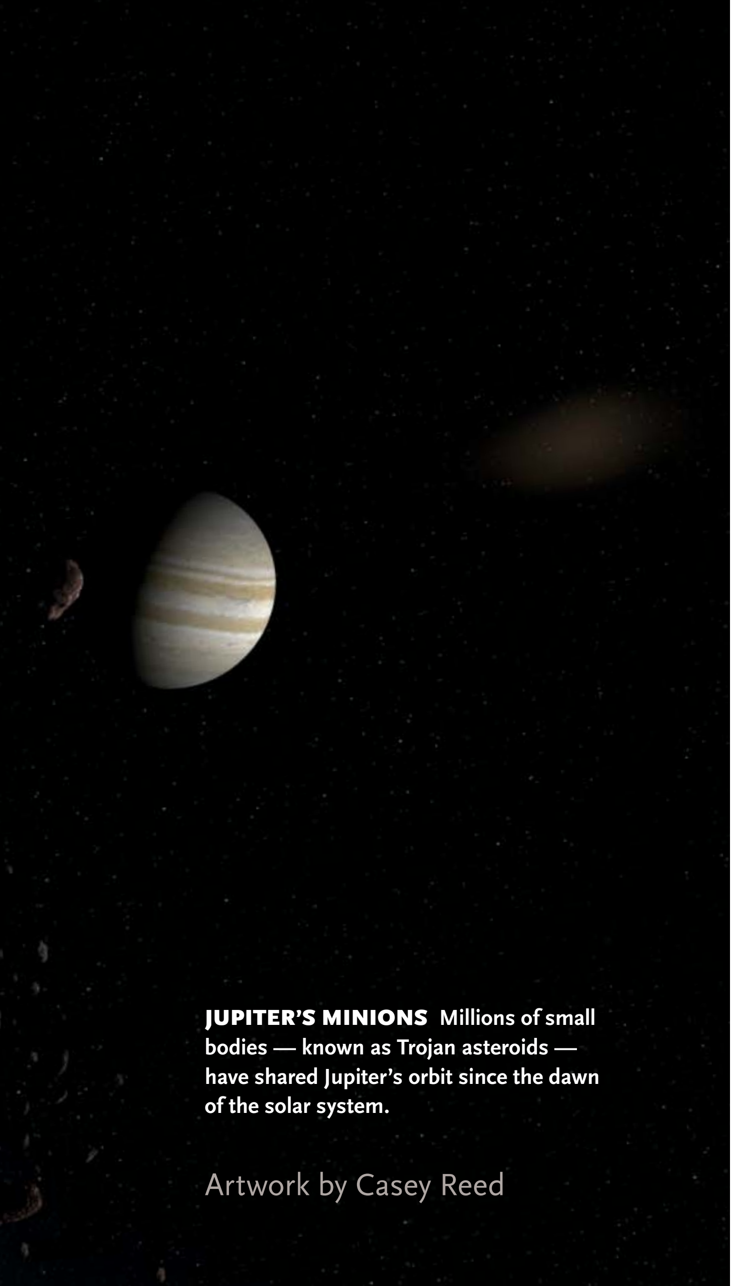
There are no big surprises, only new details. For example, the team found extensions to the Norma Supercluster, also known as the Norma Wall or the Great Attractor. The Great Attractor is the major valley in our cosmic watershed, toward which the Milky Way and many of its neighbors are being pulled by gravity, like tributaries feeding a river. The wall centers on the massive Norma Cluster, ACO 3627. The new data show that the wall stretches roughly 250 million light-years long. ✦

■ **CAMILLE M. CARLISLE**

Dancing with Planets

Millions of Trojan asteroids exist in gravitational "sweet spots" that hold important keys to our solar system's history.





JUPITER'S MINIONS Millions of small bodies — known as Trojan asteroids — have shared Jupiter's orbit since the dawn of the solar system.

Artwork by Casey Reed

Scott S. Sheppard

In our solar system's earliest days, the giant-planet region was home to a vast number of small objects. These bodies, similar to today's asteroids and comet nuclei, skipped around among the growing giants that were themselves rustling back and forth in a tumultuous planetary landscape. As the young planets grew and shifted their orbits, they likely consumed millions of these little objects and ejected billions more from the solar system.

But not all of these small, primordial bodies disappeared from the giants' immediate neighborhood. One stable population remains after 4½ billion years: the Trojan asteroids.

The Trojans move in an intricate dance with the planets. They occupy regions roughly 60° ahead of and behind a given planet in its orbit. Today we call these the L_4 and L_5 Lagrangian points, respectively, in honor of their discoverer: Joseph-Louis Lagrange (see the box below). These are dynamical balancing points at which the Sun's and planet's gravity, along with the centrifugal force exerted on a smaller, third body due to its orbital motion, are all in equilibrium. As a result, objects located at L_4 or L_5 can maintain relatively stable orbits over the age of the solar system.

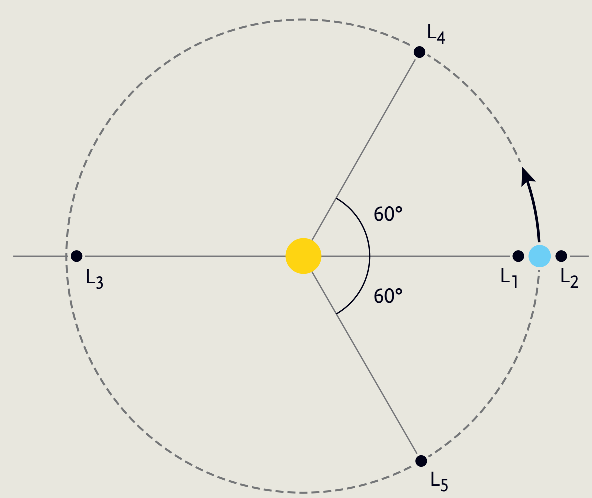
Trojans do not actually orbit right at the Lagrangian stability points; instead, they can librate around the point by some tens of degrees. In fact, these objects often occupy orbits with pronounced inclinations and eccentricities. Planetary scientists have become very interested in the locations and characteristics of the Trojans, as these small bodies tell a story about the formation and evolution of the planets.

Gravity's Balancing Act

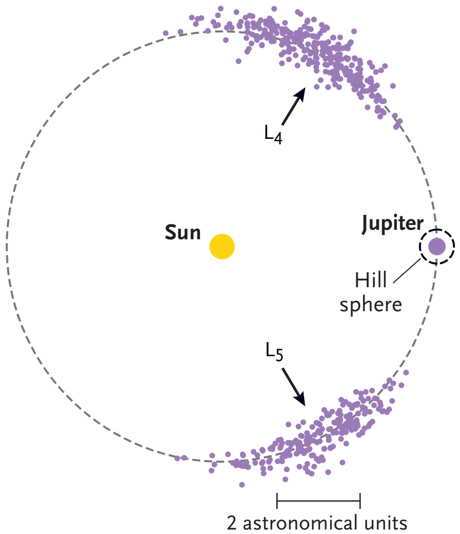
In 1765, mathematician Leonhard Euler deduced the existence of three collinear balance points in a three-body system. L_1 lies between the Sun and the planet, L_2 is just beyond the planet in line with the Sun, and L_3 is 180° from the planet along its orbit (on the opposite side of the Sun). All three have *convex stability*, such that if an object is shifted away from the balance point, it will likely leave the stability region. Thus, over the age of the solar system, objects are not expected to be stable at L_1, L_2, or L_3.

Then, in 1772, Joseph-Louis Lagrange realized that two more locations existed, preceding and trailing a planet along its orbit by 60°. Now called L_4 and L_5, respectively, these are regions of *concave stability*, meaning that objects perturbed slightly away from them will tend to go back to the stability area.

Space observatories are sometimes parked in the Lagrangian regions to exploit these gravitational properties. Once there, they require significantly less fuel to maintain relatively stable positioning with respect to Earth.



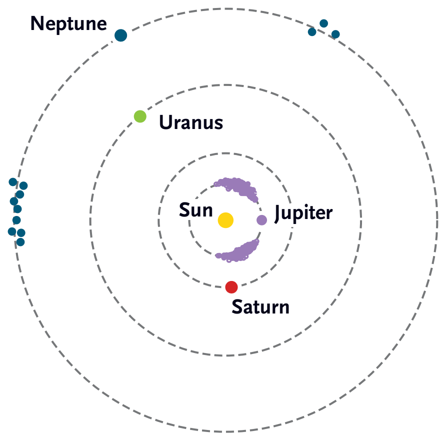
S&T: LEAH TISCIONE

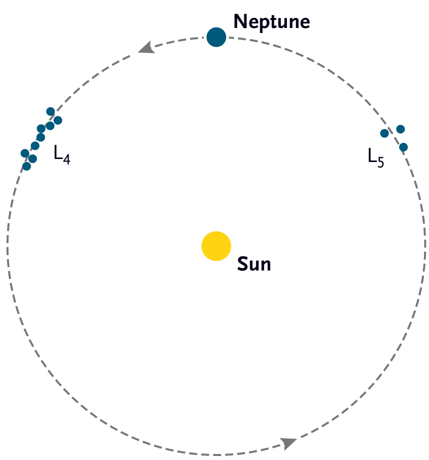


CAMP FOLLOWERS
To date, observers have identified nearly 6,300 objects in the two "camps" that accompany Jupiter. Curiously, the leading "Greek" group is roughly 50% more populous than the trailing "Trojan" group. The dashed circle around Jupiter shows its *Hill sphere*, which is the limit of stability of any of the planet's moons.

S&T: LEAH TISCIONE; SOURCE: SCOTT SHEPPARD (3)

UNEQUAL DISTRIBUTION
Jupiter and Neptune have captured many stable Trojan asteroids. But Saturn and Uranus have none, likely because their Lagrangian zones are subject to the gravitational perturbations of their massive planetary neighbors and thus not stable.





NEPTUNE'S RETINUE
Although only 12 Neptune Trojans are known, the planet's Lagrangian regions are likely even more densely populated than Jupiter's. The L_5 region appears sparser because this region is currently aligned with the galactic plane, making it harder to detect objects there.

A LUNAR CONNECTION?

If a very large object struck our planet early in the solar system's history to form the Moon, could it have been an Earth Trojan? Geochemists think such an impactor would have needed a composition quite similar to Earth's and a not-too-fast encounter velocity. An object that initially shared Earth's orbit could satisfy both of these constraints.

Picking Planetary Partners

Max Wolf discovered 588 Achilles, the first asteroid known to share Jupiter's orbit, in 1906. Observers have since found about 6,300 Jupiter Trojans — so many, in fact, that the entire population is likely only slightly smaller than that of the main asteroid belt and includes almost a half million bodies larger than 1 km in diameter.

Jupiter's Trojans are named after mythological characters from the Trojan War. The leading (L_4) region is the "Greek camp," and objects there are named after participants on the Greek side of the war. Those in the trailing (L_5) region are named after participants from the "Trojan camp" of the conflict. Each group has one object named for a combatant from the opposing side: 617 Patroclus is in the L_5 swarm, and 624 Hektor is in the L_4 swarm.

Saturn and Uranus have no known stable Trojans (though at least two of Saturn's *moons* have them). This is because the Lagrangian zones of Saturn and Uranus are highly perturbed by the gravity of the other giant planets that sandwich these worlds' orbits.

Unlike the "embedded" locations of Saturn and Uranus, Neptune is a "bookend" giant planet, as is Jupiter, making its Lagrangian regions more stable. Numerical simulations suggest 20% to 50% of Neptune's original Trojan population should have survived for the age of the solar system after any significant planetary movement. Observers discovered the first object in Neptune's L_4 location in 2001 and the first one at L_5 in 2008. The known Neptune Trojan population, currently at 12, is low only because these bodies are much harder to observe at their extreme distance from the Sun. We've started to name Neptune's Trojans after the Amazons, an all-female warrior tribe that sided with the Trojans during the war.

As for the terrestrial planets, Earth lacks any known Trojans from primordial times, probably because gravitational perturbations from Venus, Mars, and Jupiter would have destabilized their orbits over the age of the solar system. However, our planet *does* have one known Trojan in its L_4 region, a small body called 2010 TK$_7$. This was likely an asteroid in an Earth-crossing orbit that just happened to pass near Earth's L_4 region a few thousand years ago and became temporarily trapped there. Chances are good that 2010 TK$_7$ will likely escape its confinement within another few thousand years.

Mars also has a few known Trojans at both its L_4 and L_5 points. Those locations appear to be dynamically stable over the age of the solar system, so these objects could be primordial and related in some way to the Jupiter and Neptune Trojans.

Origin of the Trojans

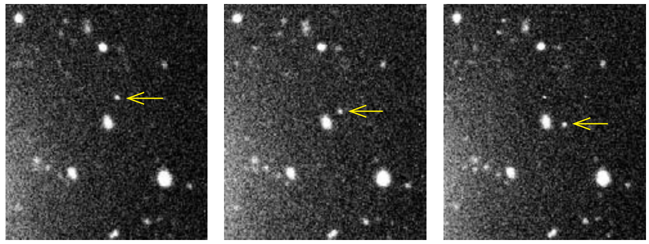
In theory, the Trojans could have formed in place and stayed put since the first stages of planet formation. After all, the Trojan regions would have been relatively stable early on, and objects could have accumulated there from the significant amounts of dust present among the growing planets. But two important observations suggest this wasn't the case.

First, most of the Trojans circle the Sun along orbits that are highly inclined relative to those of the planets. These large inclinations would have limited how much material could have been accreted from the protoplanetary disk.

Second, and more importantly, it's become clear that the major planets didn't always occupy the calm, nearly circular orbits that we see today. Instead, the primordial solar system was a chaotic place, with the giant planets likely much closer to one another. They repeatedly pushed each other around, resulting in significant shifts in their orbits. Simulations show that the Lagrangian regions would have become unstable during any significant planetary movement or migration. So the Trojans we see today were likely captured *after* the planets settled into the more stable, widely separated orbits they have now.

Conversely, small objects that approach the Trojan regions today can't become captured permanently because to do so they'd need to lose some of their orbital energy — and there's no easy way to do that. (This was not the case when the planets first formed and were still evolving, when the solar system structure was vastly different than it is now.) Instead, modern-day interlopers might linger for a time, but they eventually leave the same way they entered.

So how did all those Trojans get captured? Several mechanisms have been proposed, most operating only when the disk of material from which the planets formed still contained significant amounts of dust and gas with many small objects flying about. At that early time, friction from gas drag or higher collision rates could have allowed the capture of Trojans.



S. SHEPPARD & C. TRUJILLO (3)

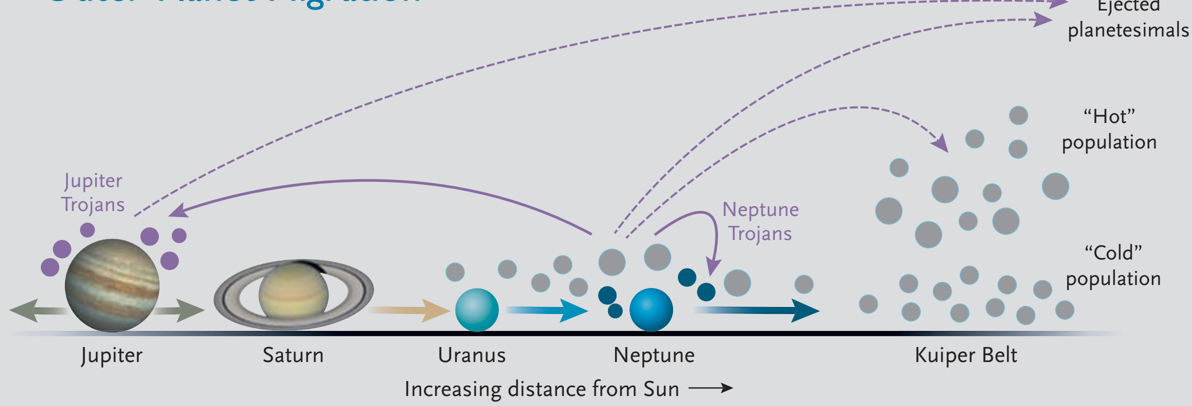
NEPTUNE TROJAN **Just 24th magnitude when discovered by the author and Chadwick Trujillo, 2005 TN_{53} has a dynamically "hot" (highly inclined) orbit that suggests Neptune captured it while migrating outward to its current orbit early in solar system history.**

However, both of these mechanisms assume that the capture-prone candidates traveled in low-inclination orbits around the Sun — in order to make energy-robbing gas drag more efficient and collision probabilities more likely. Theorists refer to these kinds of orbits as dynamically "cold." But the highly inclined orbits of the Trojans attending both Jupiter and Neptune suggest that those objects were dynamically "hot" when captured. So the gas-drag and collision scenarios are not likely the true cause.

Most probably, as proposed in 2005 by Alessandro Morbidelli (Nice Observatory, France) and colleagues, the Trojans were pawns in a dramatic interplanetary tug of war. As the giant planets shifted and migrated from where they formed to their current arrangement, they scattered countless smaller objects. As planetary formation ceased, their orbits slowly stabilized and circularized through interactions with the many bodies flying about the outer solar system. In this way small objects — even those in "hot" orbits with relatively high inclinations or eccentricities — could suddenly find themselves trapped in a Trojan region as that planet's orbit changed.

Thus the dynamics of the Trojans seem to confirm

Outer-Planet Migration



S&T: LEAH TISCIONE; SOURCE: A. MORBIDELLI & H. LEVISON

PLANETS ON THE MOVE **The outer planets occupy stable, well-spaced orbits today. But a radically different view suggests that early in solar system history they were bunched much tighter together and closer to the Sun. Gravitational interactions pushed them apart, a dramatic orbital migration that led to the capture of the Trojan asteroids.**

AUGUSTE COUDER, © MARIE-LAN NGUYEN / WIKIMEDIA COMMONS / CCA 2.5

PITCHED BATTLE Achilles (at center), a key figure in the Trojan War, is the namesake for the first discovered Jupiter Trojan.

EXOPLANET TROJANS?

Trojan objects likely exist in the orbits of exoplanets as well. Astronomers have searched for signs of these "exo-Trojans" by looking for transit events ahead and behind of known transiting exoplanets, but they've observed nothing definitive yet.

that the giant planets did migrate significantly early in the solar system's history. Moreover, this capture scenario implies that the Trojan objects likely originated in the outer solar system, not the asteroid belt. That's because the giant planets most likely pushed each other outward into a distant belt of small objects that had not yet collected into a planet due to the large volume of space and low collision velocities out there.

(As an interesting aside, it's also possible that many asteroids now occupying the outer main belt, including the dwarf planet 1 Ceres, might have originated much farther out in the solar system and then were flung closer to the Sun as the planets moved around.)

But outer-planet migration leaves one perplexing observation unresolved: Jupiter's leading (L_4) Trojan cloud has about 50% more objects than its trailing L_5 cloud does. That's not the case for Neptune, whose Trojan clouds appear to have comparable numbers of objects (based on the few currently known).

This discrepancy is challenging to explain with any of the capture scenarios mentioned so far, all of which statistically should not favor one of Jupiter's Trojan clouds over the other. David Nesvorný (Southwest Research Institute) and colleagues have suggested that this difference in populations could be the consequence of a third "ice giant" — a sibling of Uranus and Neptune — passing through Jupiter's L_5 region and scattering away many of the bodies that had accumulated there. This massive body would also have altered Jupiter's orbit significantly before the giant planet ejected it entirely from the solar system.

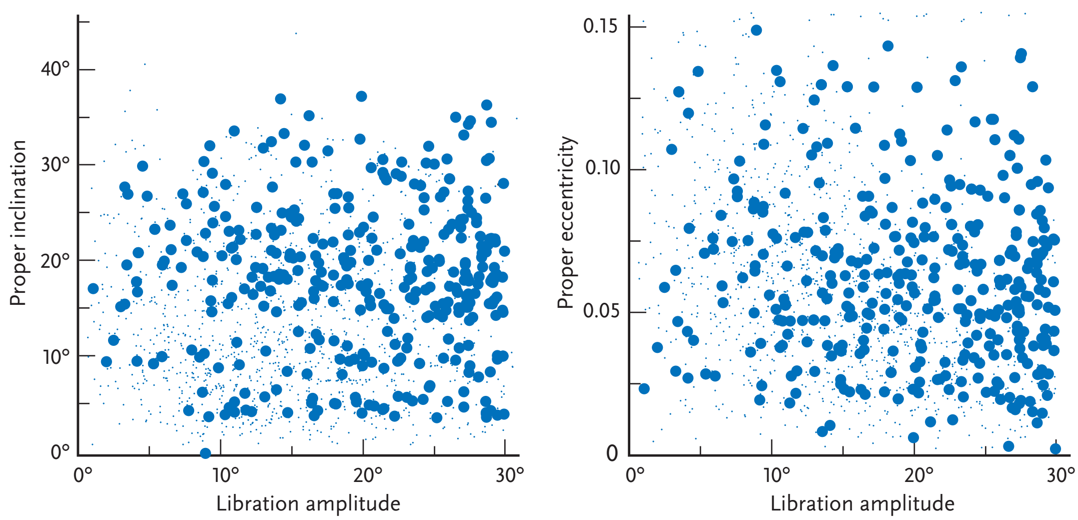
This type of planet-planet interaction likely occurred often in the solar system's early history, and it might explain how a massive, eccentrically orbiting ninth planet — if it exists (*S&T:* May 2016, p. 11) — ended up a few hundred astronomical units from the Sun.

The Stuff of Trojans

We don't yet know the Trojans' compositions, as they are relatively small and faint (Hektor, the largest, averages 225 km across). Moreover, their spectra are mostly featureless.

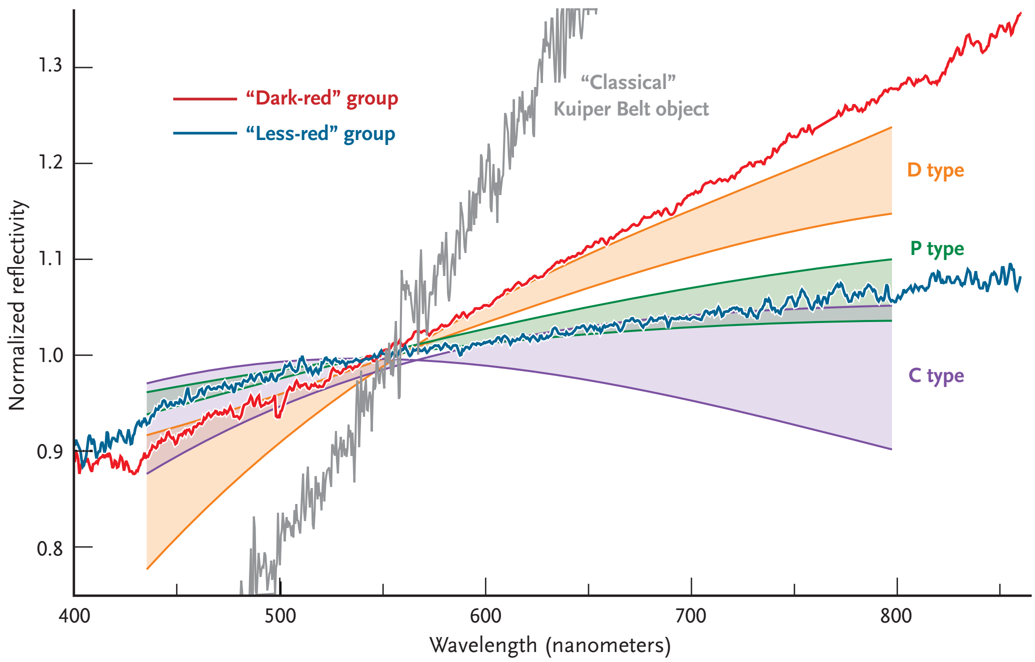
What we *do* know is that they're very dark, with average reflectivities of around 5% to 7%. Most Jupiter Trojans can be classified as either "dark red" (D-type) or "less red" (P-type) asteroids. A few have more neutral coloring, akin to the carbon-rich C-type objects seen in the outer asteroid belt. Intriguingly, a cluster of Trojans in Jupiter's L_4 cloud have very similar orbits, and most have the same C-type surface coloration. Dynamicists have proposed that this group, known as the Eurybates family, came from a single broken-up parent body.

The reddish D-types that dominate Jupiter's Trojan



"HOT" ORBITS Computer simulations of Trojans captured by Jupiter during a hypothetical early migration of the outer planets (large dots) yield the same wide variety of orbits exhibited by known Trojan objects (small dots).

S&T: LEAH TISCIONE; SOURCE: A. MORBIDELLI ET AL. / NATURE (2)



RED & REDDER Although astronomers know little about the true composition of Jupiter's Trojan asteroids, their surfaces group broadly in "dark-red" and "less-red" populations that share similarities with the D-type and P-type objects found in the main asteroid belt.

S&T: LEAH TISCIONE; SOURCE: J. EMERY ET AL. / *ASTRON. JOURNAL*

populations are relatively rare in the main asteroid belt. But it turns out that only the largest of Jupiter's objects tend to be this color. Recently, Ian Wong (Caltech) and colleagues showed that Jupiter's less-red (P-type) Trojans actually appear to dominate the population at sizes smaller than about 5 km. Perhaps Jupiter's Trojans derived from two groups of objects that formed in different locations in the solar nebula prior to their capture. Or maybe the dependence of color on size is telling us that the less-red objects are collisional fragments of the larger, redder objects. If the latter idea is correct, then the smaller Trojans would have "fresher" surfaces that have been altered less by exposure to the Sun's ultraviolet light, its solar wind, and cosmic-ray bombardment.

Geochemists usually interpret reddish surface material to be rich in carbon and complex organic molecules. But mid-infrared spectra recently obtained by Joshua Emery (University of Tennessee, Knoxville) and two colleagues suggest the surfaces of Trojans are covered in silicate dust that could be similar in composition to that in comets. If Trojans formed with lots of ices, then their interiors could still contain this initial volatile-rich material underneath outer layers that have been highly altered by "space weathering."

Determining the range of possible compositions among Jupiter's Trojans would be a lot easier if we knew their masses and thus could estimate their bulk densities. To that end, however, few Trojan binaries have been identified. One of them, Patroclus, has nearly equal-sized bodies. Franck Marchis (SETI Institute) and colleagues have analyzed the two components' orbits, and they find that the density of the paired objects is only about 0.8 g/cm^3 — less than that of water. This in turn suggests that Trojans are mostly made of porous ice, a composition more typical of a comet's nucleus than of a rocky asteroid. Since Trojans are slowly leaking out of their Lagrangian confinement, conceivably some display cometary activity if and when they approach the Sun.

Wanted: More Data

All the dynamical and compositional evidence in hand suggests that Jupiter's Trojans came from the outer solar system after the giant planets finished moving around. So they might be related to objects in the distant Kuiper Belt. Although the latter are generally redder, this difference might be a superficial consequence of the Trojans' closer proximity to the Sun's intense radiation.

One challenge to this idea is that Neptune's Trojans, which likely never approached the Sun all that closely, look quite similar to Jupiter's and likewise show a fairly uniform distribution of surface colors. Moreover, they are *not* like the more varied and redder Kuiper Belt objects, even though both populations have remained in "cold storage" since the solar system's formation.

The mysterious origins and our limited compositional information about the Trojan asteroids are why NASA has prioritized the Jupiter Trojans for a spacecraft mission of the Discovery (small budget) or New Frontiers (medium budget) class in the very near future. And while awaiting those results, ground-based observers will continue to probe these orbital curiosities for more clues to their origins and to the evolutions of their giant-planet partners. ✦

A frequent user of some of the world's largest telescopes, ***Scott Sheppard*** *is an astronomer at the Carnegie Institution for Science in Washington, D.C. He codiscovered 2008 LC$_{18}$ (the first known L$_5$ Neptune Trojan) and 2005 TN$_{53}$ (the first high-inclination Neptune Trojan).*

Is RED LIGHT Really Best?

Robert Dick

Astronomers have long used red light to protect their night vision, but there may be a better alternative.

SEEING RED Red lights are ubiquitous on the observing field, as astronomers attempt to do as little damage to their night vision as possible. But the author's research suggests that for many, red might not be the best solution.

ROBERT DICK

NO ARTIFICIAL LIGHT is good when observing, but sometimes under the stars we need it — to help us read a star map, get around, or find a piece of lost gear. We have historically used red lights, and recently we've gravitated to deep-red light-emitting diodes (LEDs). But given the range of current options, is red really the best color?

The rationale for red is straightforward. Our night vision has only 1/1000 the sensitivity to red light as to yellow, and red is the only color to which our daytime vision is (slightly) more sensitive than our night vision (see graph below). So with red light, we can use our daytime vision without "saturating" our nighttime detectors, and this is why red light preserves our dark adaptation.

But personally, I have trouble reading under red light. So I looked into other options. What I found was not only better insights into our vision but also a surprising alternative to ruby-tinting our world — one that's actually better than the tried-and-(maybe)-true red flashlight.

ALL GEOMETRIC BACKGROUNDS: BIGSTOCKPHOTOS.COM

LED VS. INCANDESCENT BULB

This article deals primarily with LEDs. An old red incandescent bulb doesn't have the same caveats as red LEDs: the bulb's glowing filament emits very little blue light, and the filter's wide bandwidth takes better advantage of your cones' sensitivities than red LEDs do.

Cones and Rods

We have two sets of visual detectors in our retina, called cones and rods. Cone cells work best in bright, daylight conditions, enabling what's called our *photopic vision*. Rods, on the other hand, provide low-light, *scotopic vision* for nighttime. During twilight, both our rods and cones operate (*mesopic vision*) and complement each other by providing a mix of fairly good resolution and faint-light sensitivity.

Our best resolution occurs with photopic vision, which can resolve features about 1 arcminute across. (That corresponds to 60 pairs of closely spaced, alternating white and black lines per degree.) From a reading distance of 18 inches, we need a resolution of less than 10 arcminutes to resolve the structure of the F at the beginning of this sentence.

In the mesopic range, we have only about half the resolution of our photopic vision. And when using our scotopic vision, we have only about a tenth.

The number and spacing of receptor cells determine the resolution of the image produced in our mind's eye. (The same principle applies to the chip's pixels in a digital camera.) The cones in our eyes provide good resolution, or *visual acuity*, because they are closely packed in the center of our view.

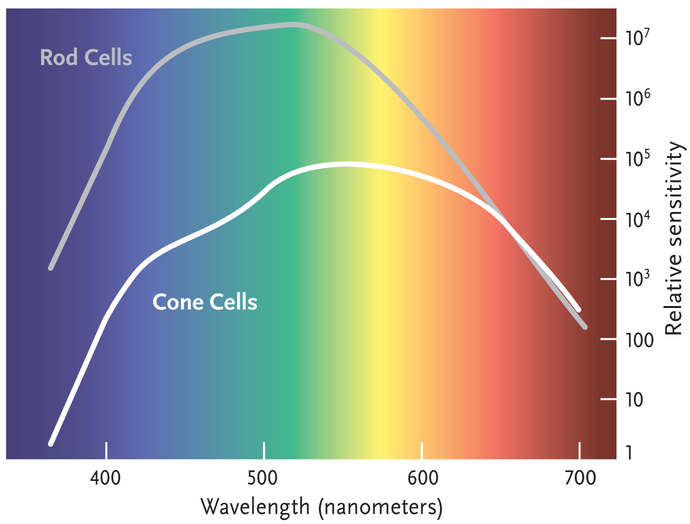
Although there are about 20 times more rods than cones, our reading ability with our rods is marginal at best. That's because of the way these cells work together. Their high sensitivity at night would produce considerable "noise," like a poorly tuned analog television, if they were not interconnected to suppress false signals to the brain. Hundreds of these cells combine to produce one signal, but this interconnectedness reduces their effective resolution to only about 1/10 that of cones. So, if our goal is to read a star map, our rods alone are insufficient. We need our hi-res cones as well for that task.

Color

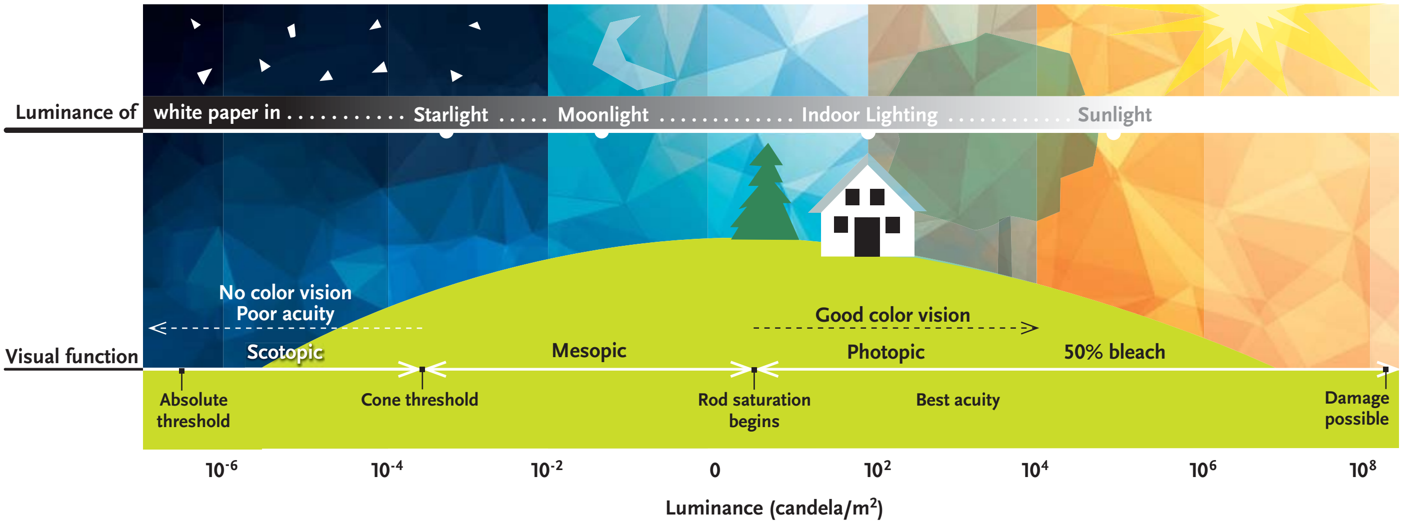
Our cone cells are also the ones that detect color. We have three types of cones, each containing one of three pigments that preferentially absorb three different wavelength ranges: L-cones, which detect the long wavelengths of yellow to red light (centered on 560 nm); M-cones, which detect mid-range yellow-green (530 nm); and S-cones, which detect short-wavelength blue (about 420 nm).

Although the three types of cones seem to have the same sensitivity to light, their impact on vision scales with how many of them we have. Only 6% are S-cones, meaning we don't see blue-lit objects very well in the

S&T: LEAH TISCIONE, SOURCE: IDO PERLMAN / WEBVISION AND THE AUTHOR



RODS AND CONES Rod vision and cone vision have different sensitivities to different wavelengths of light. Throughout most of the visible spectrum, the rod system is more sensitive to light than the three-cone system, by as much as a factor of 1,000. But at wavelengths longer than 620 nm, including the deep red of red LEDs, the sensitivities are about equal.



S&T: PATRICIA GILLIS-COPPOLA / SOURCE: D. PURVES ET AL. / *NEUROSCIENCE*, © 2001 SINAUER ASSOC.

LUMINANCE AND VISION This diagram shows one divvying up of how the visual system operates in different illumination settings. The lowest light levels only activate rod cells. Cones begin to contribute at about the level of starlight, but practical color vision doesn't kick in until around the level of moonlight. Cones are the only receptor cells active under the brightest conditions; rods bleach out.

daytime. These cells essentially tell our brain where to put a "wash" of blue in our mental image, and when combined with the responses of the M- and L-cones, we get the impression of "white" light.

The average observer has roughly twice as many L-cones as M-cones, so most of us are more sensitive to longer wavelengths. However, the ratio of L- and M-cones varies across the population, and some people have more M-cones than L-cones — making these folks even more sensitive to yellow light than to red. I must be one of them. (This is a different phenomenon from color blindness.)

Unlike our cone cells, our rods are honed to see during the fading light of twilight and nighttime. Rods are about a thousand times more sensitive to blue-green light as to red. They only have one type of light-sensitive pigment, so they can't tell which wavelength is stimulating them, hence they essentially see in black and white. This is why faint stars on a dark night, and faint deep-sky objects in the eyepiece, all have a neutral silvery gray color: we're only using our scotopic vision.

Self Experiment

Go outside at night, let your eyes adapt, and illuminate the ground with your white flashlight covered with a good yellow or amber filter. Then, look up to the clear sky. How long does it take for your eyes to recover so that you can distinguish faint stars? If it takes more than a few seconds, your light is too bright. Try the same thing with a red LED and see how fast your rods readapt.

Sensitivity

As astronomers, we are pushing the envelope of vision. Unlike our ancestors (or most of our contemporaries), we need both the light sensitivity of our rods and the resolution of our cones at the same time. Although we've long turned to red light as the solution, using deep-red light alone exacerbates our loss of visual acuity, because this color has a narrow bandwidth (only 20 nanometers for red LEDs) and triggers only our L-cones. This forces us to use *brighter* red light in order to see.

But because dark-adapted rods have nearly the same sensitivity to red light as our L-cones, red light that is bright enough to read by is sufficient to excite our rod cells somewhat. Prolonged exposure to it will still affect our night vision.

If we could take advantage of our M-cones as well by using broader-band light, could we use just enough light for hi-res cone vision while actually leaving our night vision in better shape?

In order to find this balance, we need to know how much light is enough to read by but not too much to saturate our rods. The amount of light our night vision can tolerate depends on how quickly our rods recover from exposure to it. That recovery time depends in turn on both the brightness of the illumination and how long we're exposed to it. The dimmer and briefer it is, the faster our rods will return to the dark-night threshold.

The question is, how fast do we want to adapt? It takes me less than a minute to physically move from a star map to the telescope and orient myself at the eyepiece.

If I want my vision to adapt that quickly, how low must I go? Published experiments don't go faint enough for astronomy, so the easiest way to find out how much light we can get away with is to try it!

My own experiments show that my rods recover almost immediately even after a few seconds of exposure to the full Moon's illumination on a white sheet of paper (0.1 lux, where a lux is the unit of surface brightness, defined as 1 lumen coming from 1 square meter of surface). Our threshold for reading with broadband light is 10 times higher than with moonlight, about 1 lux, and my night vision recovered from that exposure within a few seconds. At this level, we can also see some color as well, indicating that our cones are working.

Above about 3 lux, the rods take noticeably longer to adapt. This is roughly the threshold above which the rod cells become bleached.

So, when artificial light is necessary, the best choice is relatively faint light: about 1 lux, and not above 3 lux. Incidentally, this range also falls in our mesopic vision (see facing page).

LEDs' pure red light (about 650 nm) is detected by only our L-cones, and it provides poor resolution for reading or seeing hazards (such as a tripod's legs). So we not only want illumination at about 1 lux to save our rods but also light that covers a wider wavelength range, between about 500 and 700 nm, to take advantage of our M-cones as well as our L-cones.

What does this light look like? Between 1 and 3 lux, my impression of the color is pale "amber" or "candlelight." Aesthetically, it is quite pleasing.

Stamp Out Blue

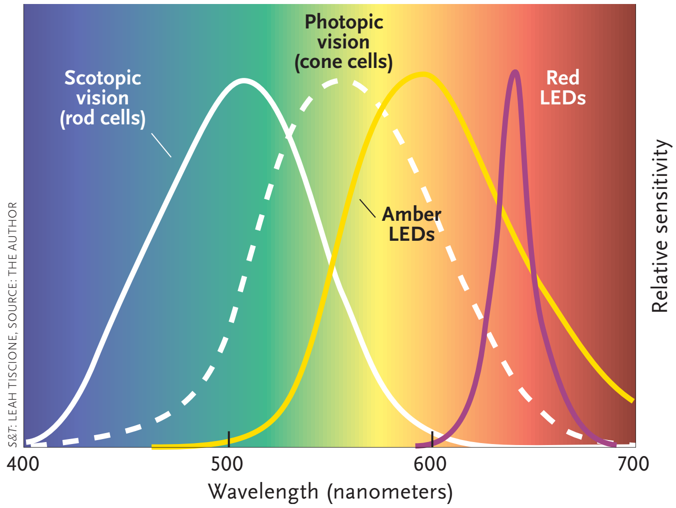
This new work goes against what has become common sense for dark-site observing. Nevertheless, we have adopted this amber spectrum and 1–3 lux illumination level for Canadian Dark-Sky Preserves.

Although the use of amber light can help us see while walking about a campground, it can also help in cities. We distinguish colors twice as well when they are illuminated by a smooth amber spectrum than when illuminated under the golden light of high-pressure sodium lamps. Those lamps don't have a continuous spectrum; their glow is mostly made up of narrow emission wavelengths specific to sodium, which only let us see colors that match up with these spectral features.

Worse, the blue component of "white light" city lamps provides very little information for our visual acuity, yet it cripples our night vision, making it difficult to see into more shadowed areas. So using amber light, at rational illumination levels, actually improves our ability to see at night. The International Dark-Sky Association is on a campaign to educate lighting installers on this fact.

Where can you get amber LEDs? Most large LED manufacturers make them. Close variations are available from Lumiled (Philips), CREE, and Nichia. Before you buy, check the LED's spectrum and ensure it does not emit light at wavelengths shorter than 500 nm. The peak wavelength should be about 590 nm, which is at the boundary between orange and yellow.

It must be emphasized, of course, that any artificial light will compromise our night vision. Observers pushing their visual limits would not use any artificial light! But amber gives us more visibility with less light. So, when you have to see in the dark, choose amber. ✦



AMBER VS. RED LEDS Our rods and cones have different peak sensitivities: rods in the green, cones in the yellow. These are compared in the graph above with the spectra of amber and red LEDs. Red LEDs only trigger our L-cones, so in order to be bright enough for us to read by their light, red LEDs must also be bright enough to bleach rod cells. Conversely, amber light excites both the M- and L-cones. Using it, we can see and read well at a lower illumination level that will permit rods to quickly recover.

COLOR TEMPERATURE

Another way to select LEDs is by their color temperature. Color temperature is the approximate temperature of a solid, hot surface that "looks" like the desired color. The color temperature for amber is about 1900–2100 kelvin.

Robert Dick is a professional engineer and part-time astronomy professor. His interest in the bio-impact of light began in the late 1990s, when he developed the Canadian Dark-Sky Preserve Program for the Royal Astronomical Society of Canada. This culminated in the creation of the Canadian Scotobiology Group, Inc. For this and other contributions, he was named Fellow of the RASC in 2015.

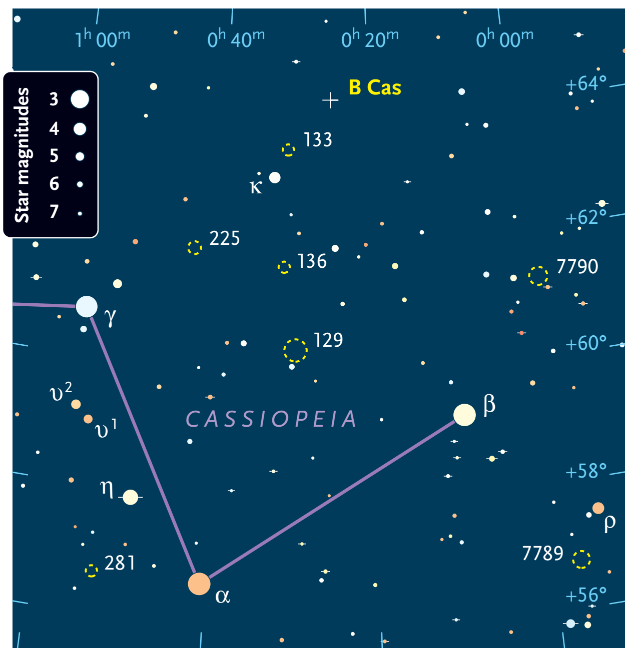
The Elusive B Cassiopeiae

In which we track and capture a supernova remnant.

David Tosteson

For astronomers of 16th-century Europe, the heavens were unchanging and immutable. It took the dramatic appearance of a new object in the sky to challenge that opinion. Danish astronomer Tycho Brahe was 26 years old on November 11, 1572, when a "new star" in Cassiopeia exploded into, and forever altered, the collective human understanding of the allegedly static universe.

Although not the first to spot the event now cataloged as Supernova (SN) 1572, Tycho was the most thorough of all observers to document its light curve. His precise data would be used not only in his time, but more than three and a half centuries later to determine the explosion's origin. Copernicus fired the first shot against the fortified concepts of Aristotelian and Ptolemaic dogma, but this new, inexplicable star that ultimately inspired Tycho's 1573 book, *De nova stella*, convinced many of his contemporaries that a new cosmology was needed.

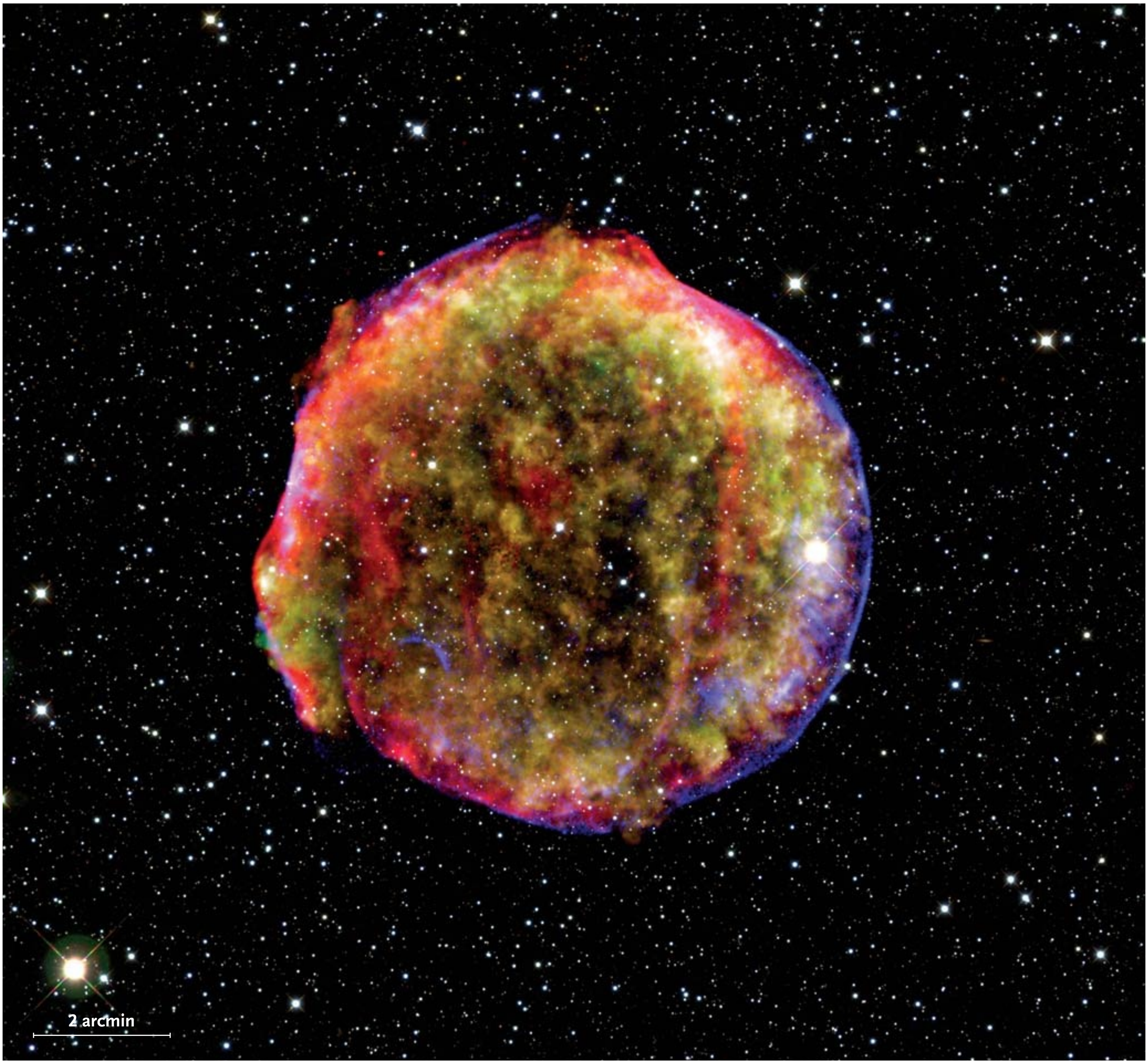


In the pre-telescopic era of the late 1500s, the light from this stellar explosion remained visible to the naked eye for 16 months, from November 1572 until March 1574. When the nova was at its estimated –4.0 maximum magnitude around the middle of November, it was visible even in daylight. Even as its light faded from view, the remnant of the supernova expanded. It continued to do so, unobserved by human eyes for the next 375 years.

The Arc of Observational History

The optical observation of Supernova Remnant (SNR) 1572, also cataloged as B Cassiopeiae, or B Cas, started in the 20th century. Walter Baade, the German astronomer who defined the category of bright stellar explosions as "supernovae" in 1934, reexamined Tycho's data to produce a light curve smoothed by quarter-magnitude steps. After comparing it with similar curves, such as that of Kepler's Supernova of 1604, he categorized SN 1572 as a Type I object that showed a linear decrease in brightness. In his 1945 *Astrophysical Journal* paper, Baade noted that no apparent remnant of SN 1572 was visible on existing photographic plates. However, he held out hope for future observations to be made with the Hale telescope, then under construction at Palomar Observatory. Dedicated in 1948, the 200-inch reflector possessed four times the collecting power of the largest instrument then extant, the Hooker 100-inch reflector at Mount Wilson.

Baade imaged the area around SN 1572 with this powerful new instrument on November 23, 1949, and on the red plates detected nebulosity on the eastern edge of the SNR. But he didn't report these findings, concluding instead that the filaments were too distant from the point of origin to be related to Tycho's exploded star. Thus, credit for the discovery of the SNR goes to Hanbury Brown and Hazard (Jodrell Bank), who detected it in radio wavelengths in 1952. Baldwin and Edge (Cambridge University) corrected position errors in 1957, and



X-RAY: NASA / CXC / SAO; INFRARED: NASA / JPL-CALTECH; OPTICAL: MPIA, CALAR ALTO, O. KRAUSE ET AL.

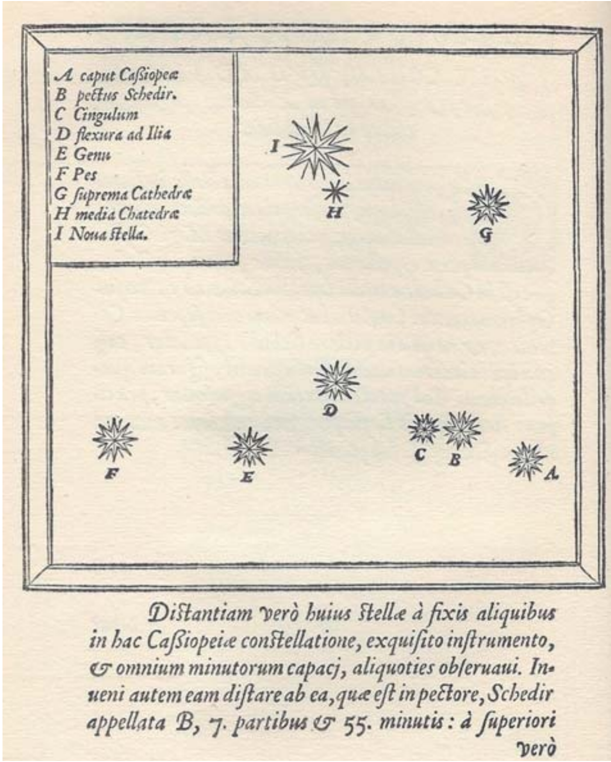
FOUR CENTURIES LATER **This composite image of the Tycho Supernova Remnant combines X-ray, infrared, and optical observations. The X-ray data (green and yellow) shows an expanding cloud of debris; the boundary of the shockwave is also visible in X-ray (blue). Infrared observations reveal the heated dust in the area (red). The field stars (white) were imaged in the optical wavelengths.**

B Cassiopeiae was subsequently cataloged in 1959 as 3C 10 in the *Third Cambridge Catalogue of Radio Sources* (3C). As it turns out, B Cas is the second-brightest radio object in that constellation after Cas A, itself the most luminous radio source outside our solar system.

Prompted by these radio surveys, Baade repeated his plate observations with the 200-inch telescope in 1955 and 1957, ultimately deciding that the filamentary structure he'd detected earlier was indeed related to Tycho's supernova. He'd been thrown off by the remnant's very large proper motion. In 1970 Sidney van den Bergh (University of Toronto) used the same telescope to take a two-hour red exposure of the same field with a more sensitive emulsion. After studying the plates, he noted two new sections of nebulosity at the remnant's northeastern and northwestern edges. Based on these images, taken 21 years after Baade's initial attempt at detection, van den Bergh estimated the expansion rate of the nebula at ~0.19″ to ~0.21″ per year.

The Guilty Party

Competing theories exist regarding the creation of Type 1 supernovae like the one watched by Tycho and his contemporaries. In one scenario, two white dwarfs



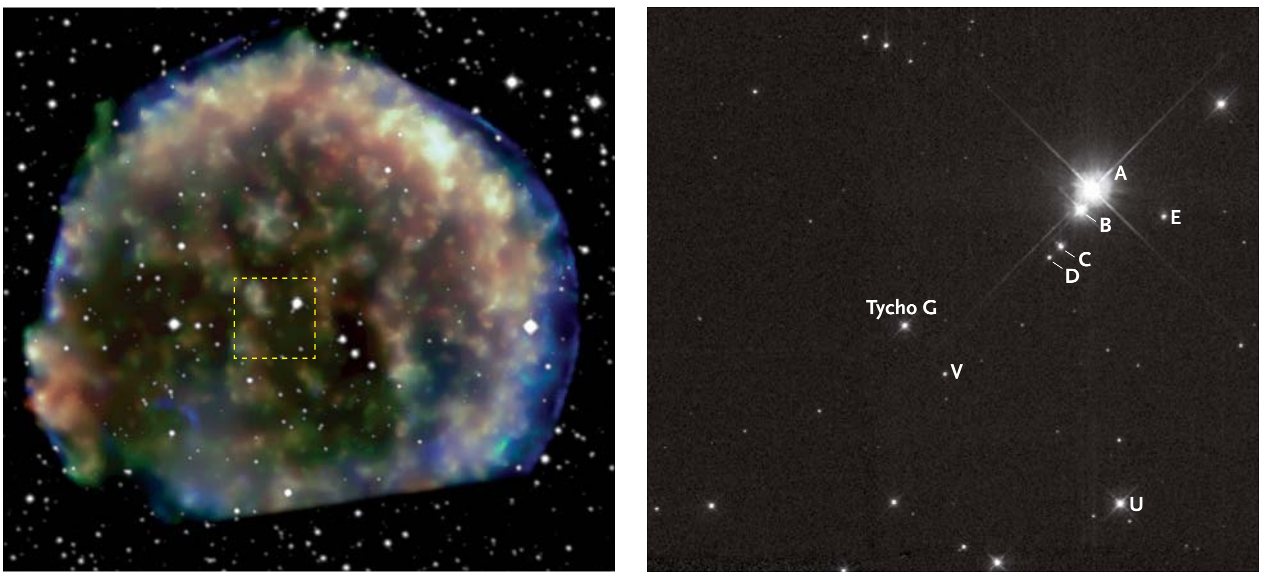
DE NOVA STELLA / PUBLIC DOMAIN

A NEW STAR Tycho measured the angular distance of the 1572 supernova (marked I in his chart) from Beta (β) Cas (marked G) as 5° 21′ and from Gamma (γ) Cas (marked D) as 5° 1′.

merge, either as the result of a single, dramatic collision or a slow drawing together in a gravitational spiral, to form a supermassive star that then explodes. In another scenario, a single white dwarf gravitationally accretes material from a nearby "normal" companion star until compression triggers a thermonuclear explosion. The white dwarf explodes, altering the chemical state of the companion star and affecting its radial velocity and proper motion. Astronomers think both causes are likely to occur, but the second is most frequently proffered to explain the creation of B Cas.

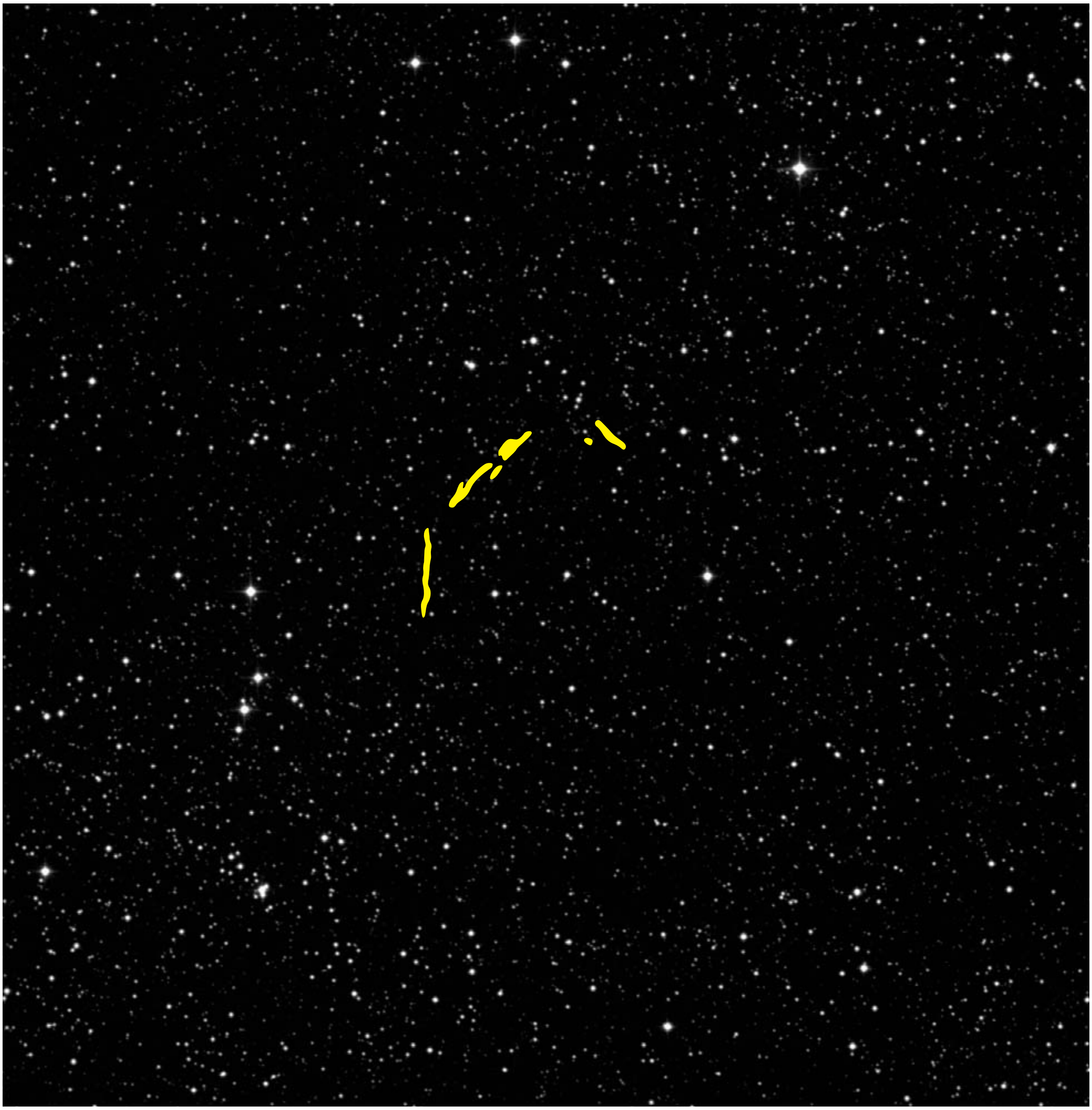
Theories also differ as to the identity of the companion star of the pre-supernova white dwarf. My original interest in observing B Cas was spurred by a 2005 report on the relationship of the SNR to the *G*-type star "Tycho G" (the second "G" here comes not from the star's spectral type but its place in the list of possible candidate companion stars, labeled "Tycho A" to "Tycho V") (*S&T:* Feb. 2005, p. 22). While spectroscopic and metallicity analyses point to Tycho G as the putative companion star, recent studies suggest otherwise. Tycho G may fall outside the region most likely to include an ex-companion star, and discrepancies in Tycho G's velocity and motion may be the result of other stellar processes.

Regardless of the final ruling on Tycho G's role in the explosive event, looking for this dim star adds another element of difficulty to the already tough task of visually observing B Cas. It's clear from the efforts of professional astronomers that spotting the SNR in the optical range — with or without the possible companion — has always been a difficult game. But how obtainable is a view of it for backyard observers? As Howard Banich's account of viewing Cassiopeia A shows, some supposedly unobservable objects fall well within reach of amateur scopes (*S&T:* Dec. 2014, p. 60). His article encouraged me to reconsider my own observations of Cas A, which I viewed with my 25-inch scope in 2003, and later with instruments of 15 and 32 inches of aperture, as well as my notes on B Cas and Tycho G.



NASA / ESA / P. RUIZ-LAPUENTE (UNIVERSITY OF BARCELONA) (2)

POSSIBLE COMPANION A view of Tycho G and its starfield, taken by the Hubble Space Telescope Wide Field Planetary Camera-2, is superimposed on a Chandra X-ray image of the expanding supernova remnant.



POSS-II / PALOMAR OBSERVATORY / CALTECH / STSCI

GHOSTLY REMAINS **The faintest trace of nebulosity on the eastern and northwestern area of the supernova can be seen on the POSS-II red chemical plates taken with the Palomar Observatory's 48-inch Samuel Oschin telescope.**

Hunting the Remnant

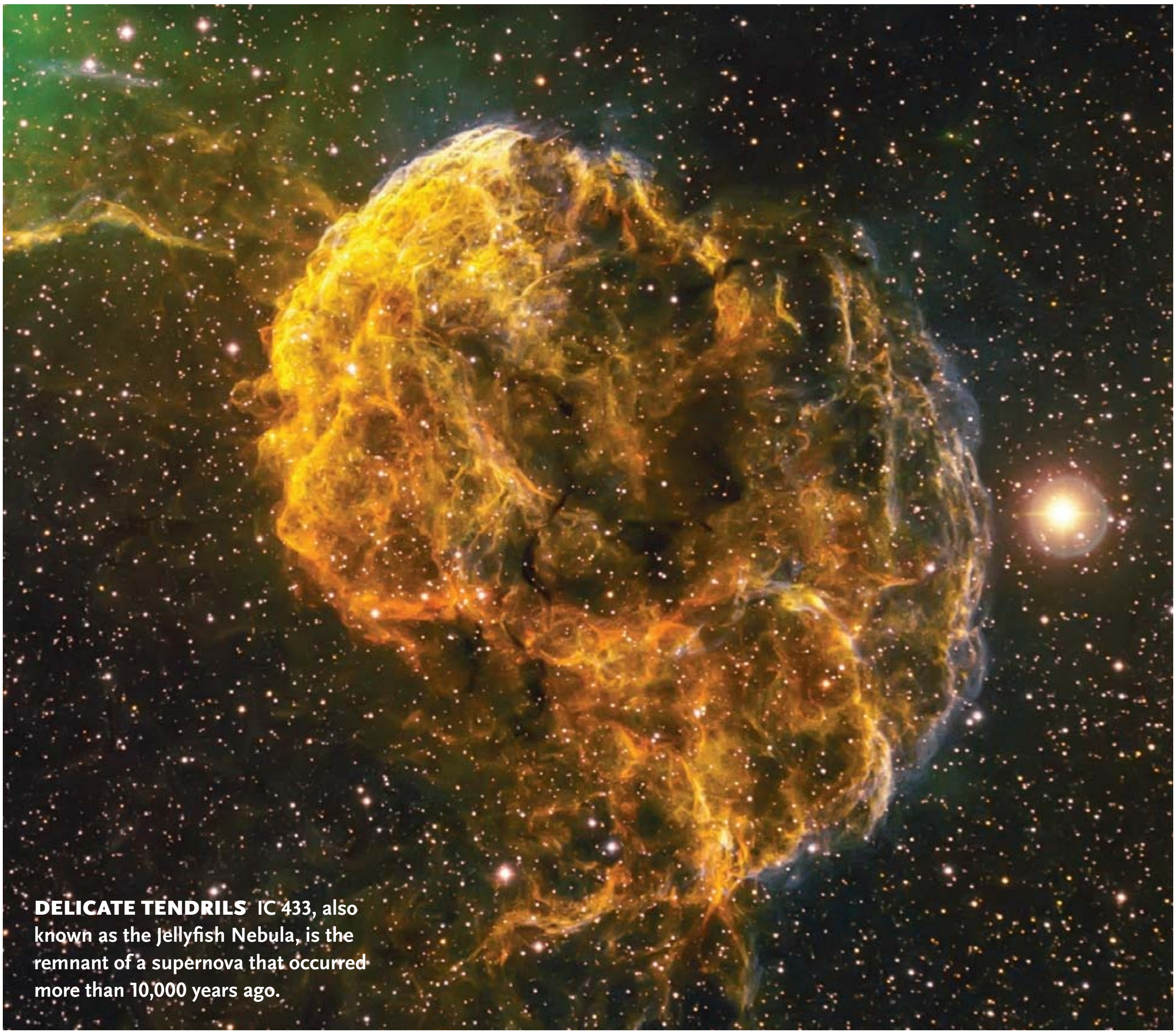
To my knowledge, there were no published visual sightings of B Cas by amateur astronomers prior to 2006. With an extremely low surface brightness, B Cas is a ghostly shell that spans about 20 light-years, or 8′ visually. Techniques for observing SNRs are similar to those for ultra-dim galaxies. SNR possess emission lines, but most of the fainter ones don't respond to filters. In March 2015 Myung Gyoon Lee (Seoul National University) et al. published a study on SNRs in M81, demonstrating that nearly all of their spectra showed O III lines at 5007 angstroms, but the lines were significantly weaker than those found in planetary nebulae. The Hα emission lines were much stronger, but these are most useful for imaging. (One exception to filter enhancement would be the Veil Nebula in Cygnus, the view of which is markedly improved with an O III filter.) I couldn't count on filters enhancing the view of B Cas for me.

To aid my search, I made finder charts accompanied by images from the Second Palomar Sky Survey (POSS-II) red plates as well as those from the results van den Bergh published in the *Astrophysical Journal* (1971). The eastern and northwestern areas of the SNR are faintly seen on the POSS-II red plate, serving as a guide to what might be visible in my large reflectors. I also printed a Hubble photo montage to take into the field. There's no substitute for having an image to compare with faint objects, but I suggest observing the field containing the target first, and using the image only for confirmation; otherwise, you can be misled into imagining you see something you really don't. In the case of SNRs, you should also keep in mind that they're expanding and may be in a different place than that shown in the image. For my finder charts, I used Megastar with USNO-A2.0 stars down to 21st magnitude to isolate the B Cas field 1.0° northwest of NGC 133.

Well-prepped and well-equipped, I transported my 15-inch f/5 reflector to a resort on Gull Lake in north-central Minnesota during a family vacation in early August 2006. I set up in a dark area known to have Sky Quality Meter (SQM) readings in the 21.0 range, indicating a very dark site. I rated the seeing as 7-8/10 and transparency 8-9/10. Cassiopeia was between 65° and 70° above the horizon between 2 and 3 a.m. as viewed from latitude 46.5° North.

I started my search with a 7-mm eyepiece, but when it wasn't adequate to spot the nebulosity, I bumped up the power. With a 3.5-mm Type 6 Nagler eyepiece at 544×, I spotted nebulosity on the northwest side of the SNR four times in 20 minutes, rating it extremely faint. The nebulosity appeared about 10″ long and 2-3″ in width, oriented northeast to southwest. It nearly touched a faint star to its northwest. A similar star rested 15″ northwest of that star. I also managed to tag Tycho G at RA $00^h\ 25^m\ 19^s$, Dec +64° 08′ 18″ (J2000.0). Though sources give its magnitude as +19.1, I didn't have much difficulty observing it in such fine conditions.

Try as I might, I wasn't able to see the eastern portion of the SNR in the 15-inch scope, but I gave it another shot a few weeks later from my home in east-central Minnesota, where the SQM attains 20.7 but the sky



FOCAL POINTE OBSERVATORY / BOB FRANKE

DELICATE TENDRILS IC 433, also known as the Jellyfish Nebula, is the remnant of a supernova that occurred more than 10,000 years ago.

generally isn't as transparent. On the other hand, I was working with a lot more aperture. I used my 32-inch f/4 reflector to view the remnant's eastern nebulosity with the same 3.5-mm eyepiece at 929×. Just southeast of a flattened triangle of 17- to 18th-magnitude stars, the fragment tipped north to south. It was several arcseconds wide and between 15-20″ in length. This location is just east of the position shown on the POSS-II red plate, a change in position that correlates with the SNR's expansion rate of ~0.2″ per year as calculated by van den Bergh. My friend Tim Parson confirmed the observation. On that night and again a few nights later with the same equipment, the SNR was seen quite well with averted vision and, at times of good seeing, was on the edge of direct vision. Tycho G was easily seen in the 32-inch.

Take a Shot At It

If you're interested in observing supernova remnants, you may find it helpful to start with brighter and closer objects, then work toward fainter members like SNR 1572. An excellent resource, updated regularly, is Dave Green's Catalogue of Galactic Supernova Remnants from Cambridge University (**mrao.cam.ac.uk/surveys/snrs/**). Images of SNRs in professional journal articles can be correlated with POSS-II data to determine visibility. Messier 1, the Crab Nebula in Taurus, is one of the best training targets; at magnitude +8.1, it's easily visible about 1° northwest of Zeta (ζ) Tauri with a small scope or binoculars. The challenge with M1 is to view the 16th-magnitude pulsar energizing the nebula. Similarly, IC 443, the Jellyfish Nebula in Gemini, is a large and beautifully detailed structure, offering hours of reward for careful observers. It contains a neutron star on its southern end that's plowing through nebular gas, leaving an observable wake.

After whetting your optical appetite on these targets, more difficult fare awaits. Objects for advanced observers include Simeis 147 in northern Taurus, near the Auriga border. This 200″ remnant is diffuse, with only several of its brighter fragments visible. Cassiopeia A is surprisingly accessible, and it has been seen in a 9.25-inch scope by veteran observer Bill Gates. In its quadricentennial year, I observed several of the fragments of Kepler's SNR (1604) in Ophiuchus with my 25-inch scope at 454× without a filter. But I recommend observers of SNRs try different filters, particularly the O III. Having a filter slide that allows rapid switching between filters enhances the view and improves the chance of recovering these faint objects.

Lastly, don't give up if you don't capture your prey on the first attempt. For objects at the edge of visibility, sky conditions are critical. I keep a list of "challenge" targets for periods of excellent seeing and clarity, and in unusual cases have pursued objects for over a decade before they succumbed to diligence. Visually observing historical supernova remnants is rewarding on many levels. Their study can take us back in time to delve more deeply into the context of their occurrence, and they show how unexpected findings can push science and understanding forward. Technical observing obstacles hone skills that create a desire to seek new goals, extend visual limits, and encourage others to pursue challenging targets.

SUPERNOVA SPAGHETTI **With careful planning, the filamentary structure of the supernova remnant Simeis 147 can be teased out of the starfield in northern Taurus.**

Nothing Ventured, Nothing Gained

Over my three decades in this hobby, my rate of visually recovering difficult objects has risen greatly. I've learned that with persistence and planning, many objects previously considered invisible through a telescope can be seen. I've experienced satisfaction in these moments when an observation offers a sense of being part of an event spanning centuries of time. In the case of SNR 1572 we have, through a shared love of the sky and careful documentation, a connection with one of the great observers of the past. Maybe someone four centuries from now will find fresh value in the remains of this elusive star. ✦

David Tosteson *has been an amateur observer for over 30 years. His main interest is observing rare and unusual deep-sky objects, including quasars, black-hole phenomena, and distant galaxy clusters. When he's not working as a family practice physician just north of St. Paul, Minnesota, traveling to regional star parties and solar eclipses with his wife keeps him busy.*

Leo by Night, Lions by Day

TRAVEL TO THE HEART OF AFRICA'S NATIONAL PARKS FOR AN OBSERVING ADVENTURE OF A LIFETIME.

Nick Howes

I've been fortunate to have observed from some exotic locations in a quest for astronomical Nirvana. From Kitt Peak to the mountains of Japan, I've visited some of the world's great observatories and viewing locations. So when the offer to lead an astronomy adventure came courtesy of African Environments, I simply couldn't refuse.

Our goal was to enjoy a week observing under the inky-black skies of Tanzania's Ngorongoro Conservation Area, as well as in the famous Serengeti National Park. Outside of the rainy season, Tanzania boasts clear skies for more than 85% of the year. The country is just south of the equator, which presents observers the opportunity to enjoy views of the best objects in both the Northern and Southern Hemisphere skies.

The trip was dubbed "Lions by Day — Leo by Night," indicative of the wildlife we might encounter with our safari and astronomical activities. Our guests first spent a night at the Arusha Hotel on the foot of active volcano Mount Meru where we all had a chance to meet and recover from any jet lag. We then departed for three nights under the dark skies of the Ngorongoro Conservation Area in northern Tanzania.

Daylight Adventures

As anyone who's done a bit of astro-tourism will tell you, daylight activities can make or break a trip almost as easily as the observing activities. This is especially true if you're traveling with family members with little interest in astronomy. So while we were all eager to get to the "Leo" part of our expedition, the "Lion" part was also crucial to the trip's success.

The Crater Highlands in the Ngorongoro Conservation Area were around 100 miles from our arrival point in Arusha, so after an early breakfast, we headed out across the landscape. Our guides had spent several years on location and were intimately familiar with the sights and creatures we encountered on our journey. With their ability to spot animals at incredible distances, their keen eyesight would put a hawk to shame.

The roads to Ngorongoro were well cared for, so we enjoyed a very smooth ride all the way from Arusha up to the entrance to the Conservation Area. Even inside the park, the well-worn tire tracks weren't the bumpy off-road excursions I had experienced a decade earlier while visiting Kenya.

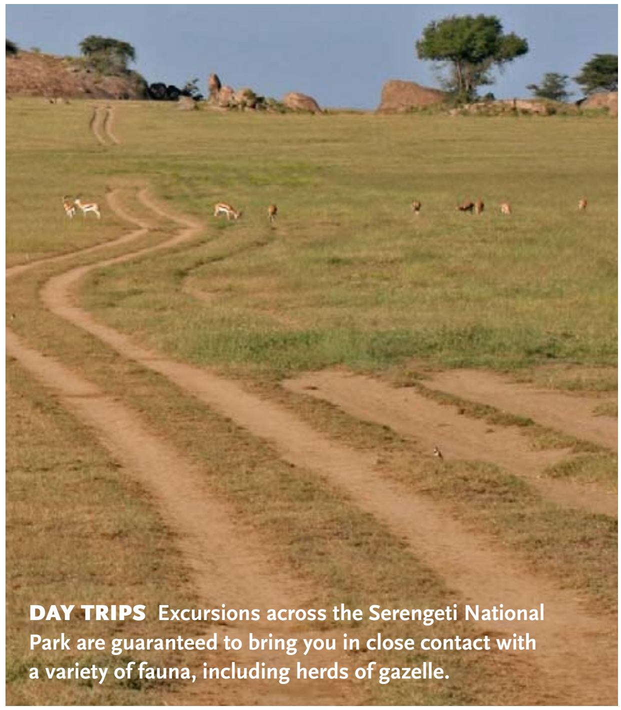
The Ngorongoro Crater is the largest drained volcanic caldera in the world. Covering over 100 square miles, it's part of the larger Conservation Area designated as a UNESCO World Heritage site that receives about a half-million visitors a year. The sprawling 14-mile-wide crater is sometimes likened to the fictional "Jurassic Park" grounds, with a rich ecosystem home

SAFARI SKIES Jewels of the Southern Hemisphere heavens, including the Eta Carinae Nebula and the Large Magellanic Cloud, are some of the targets easily visible from Tanzania. BABAK TAFRESHI to more than 25,000 animal species. These include rhino, leopards, 7 prides of lions, and several hundred bird species, combined with millions of wildebeest migrating through each year.

Our first base was on the western crater rim at Mysigio Camp (close to Mysigio Village) surrounded by lush greenery and grazing cattle. I'll never forget gazing out across the crater for the first time. The vast plain of the crater floor, with Lake Magadi in its midst, was spotted with migrating wildebeest and flamingos, while rhinos basked in the sun, and several lions looked on at the smorgasbord of prey in front of them with seeming delight.

The campsites were far from any town or city, with a limiting magnitude an astoundingly dark 6.2 — perfect for observing. At an altitude of about 2,000 feet, our camp was free of mosquitos, and the skies' transparency was nearly perfect after sunset. It was clear from the first night that we were in for some spectacular observing.

On arrival we were shown to our tents, though "tent" is a loose term, as these were more akin to luxury hotel rooms. Each was the size of a spacious apartment, with solid wooden beds, washrooms, and separate showers. Apart from the tent rooms was the "break out" tent, populated with books covering not only the astronomical aspects of our trip, but also the local flora and fauna. Drinks, snacks, and solar-powered charging points for cameras and other electronics were also readily available.



DAY TRIPS Excursions across the Serengeti National Park are guaranteed to bring you in close contact with a variety of fauna, including herds of gazelle.

NICK HOWES

Nights at Ngorongoro

Due to the remoteness and travel time across country, our observing equipment needed to be lightweight but with enough viewing capability to satisfy even seasoned observers, and it had to operate for days on battery power. Since Tanzania is just south of the equator, polar alignment on equatorial mounts would be tricky because both poles were very close to the horizon. Our emphasis was on visual observing as many objects as we could each night, so we decided to avoid the complexities of equatorial tracking and opted for what turned out to be a perfect setup for the job: a 130-mm Sky-Watcher refractor on an alt-az Go To mount. The scope provided wonderful wide-field views of many southern objects, and the mount did double-duty during the day with a Solarscope SV50 Hydrogen-alpha solar telescope. Both scopes provided satisfying views for all our guests, as well as for many of the local staff and villagers.

Most of the guests would break for a short siesta in the afternoon after coming back from the daytime adventure taking in the days' views of lions hunting gazelle or eagles soaring overhead. Then after cleanup and dinner, a few of us, along with our Maasai guards (the Maasai lease the land where the campsite is located), would head out to prepare for the night's observing activities.

Each evening, we were out ready to observe by about 7 o'clock. The Sun sets at a near-vertical angle near the equator, so the time between sunset and astronomical twilight is quite short compared to mid-northern latitudes, and we were observing within 20 minutes. Generally, we could plan on a good 8-hour stretch of observing ahead of us. After a quick two-star alignment, the Sky-Watcher Go To performed superbly, allowing us to slew to countless targets many of us had never seen before, night after night.

BIG CATS Several prides of lions populate the Ngorongoro Conservation Area and Serengeti National Park. Both observing locations were well-guarded at night to deter any nocturnal predators.

NICK HOWES

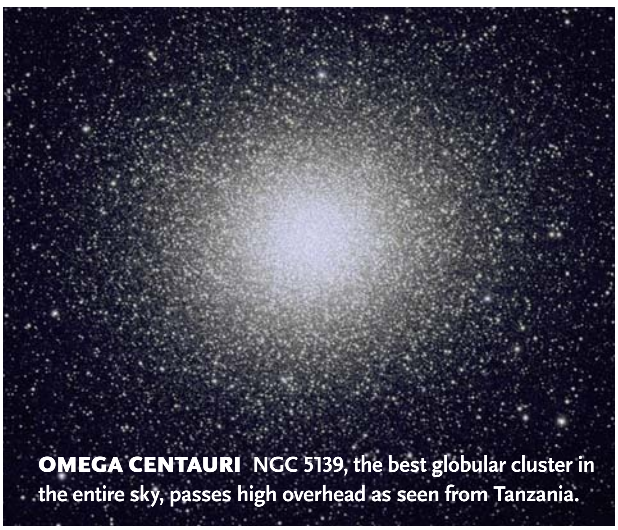
S&T: LEAH TISCIONE, SOURCE: © 2016 GOOGLE

Jupiter dominated the skies each night, and under such dark skies, it literally cast shadows. The Messier objects, particularly those with southern declinations such as M83 and M42, elicited gasps of delight from our guests, while the Small and Large Magellanic Clouds were show-stopping targets that provoked audible squeals of joy when viewed through the eyepiece. Our 5-inch scope seemed to perform like an 8 under such dark and steady skies, enabling us to trace out structural detail in the extremities of must-see targets like 30 Doradus, the Tarantula Nebula, and NGC 3372, the Eta Carinae Nebula. The massive globular cluster Omega Centauri (NGC 5139) filled the eyepiece with millions of stars, drawing shouts from one happy guest that had us all in fits of laughter.

Knowing that Tanzania has a rich history of large impact events, I brought along a range of meteorites from my personal collection. These were especially handy when observing the planets and a few of the brighter asteroids and other rocky bodies visible at the time. I enhanced the experience for many of our guests by first showing them Mars and the thin crescent Moon, and then handing them a real piece of each to give them a tangible connection to the targets they were observing.

Serengeti Skies

After three nights at Ngorongoro, we moved on to the Serengeti National Park. Our next location in the Nabi Hills region provided an almost 360° flat panorama to enjoy, with the same level of accommodations as we had in the Crater Highlands. As soon as the camp lights were switched off, we were ready to begin another few nights of excellent observing. Once again we were blown away with the views of unfamiliar objects as diverse as the Silver Dollar Galaxy (NGC 253), all the way down to the Jewel Box Cluster. Star colors in this bright cluster took on a vivid hue under such pristine skies.



NICK HOWES

OMEGA CENTAURI NGC 5139, the best globular cluster in the entire sky, passes high overhead as seen from Tanzania.

GERALD RHEMANN (2)

CELESTIAL SIGHTS Apart from the Magellanic Clouds, other bright galaxies, including NGC 253 (top) and M83 (above), were excellent targets for our 5-inch telescope.

On our last night of observing, a huge fireball lit up the sky. I stood for a while wondering if the meteoroid had made it to the ground and would one day be discovered and identified. Then it struck me that with the wildlife all around us, how rich and diverse a planet we live on. I imagined what the early inhabitants must have thought of the skies. The vast Milky Way stretching overhead, bright planets lighting up the sky, occasional comets. . . . It must have evoked a real sense of wonder.

A Maasai chief and his son joined us for observing on more than one occasion. They were both taken aback by their first view of prominences many times larger than our planet dancing along the limb of the Sun. The chief then told me, “I never imagined it would look like this! The Sun for us, brings life to us all, not only to our crops, but to our livestock. . . . To see it in this way is something I will never forget.” Hearing the roar of lions in the distance as I stared in quiet contemplation at the Large Magellanic Cloud that evening, I thought to myself, “Neither would I.” ✦

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*Nick Howes will lead an eclipse tour to Tanzania late this summer. For information, visit **africanenvironments.co.tz**.*

The Nebula War

ALAN HIRSHFELD

More than a century ago, a clash between two pioneer sky photographers deepened the growing split between amateur and professional astronomy.

In 1890, astronomy was the enterprise of a scattered coalition of amateur and professional scientists working on a roughly equal basis. Both conducted essential observations, innovated new technology, published papers, attended conferences, joined scientific organizations, and received awards of merit.

But as that crucial decade progressed, distinctions between the two groups rapidly began to widen — in terms of academic credentials, mathematical acumen, and, most devastating to the amateurs, the scientific value of their work. Disruptive new technologies — photography and spectroscopy — were fast overtaking traditional visual observation. Productivity imperatives, and the escalating cost of leading-edge equipment, increasingly displaced gentlemen's private observatories in favor of externally funded institutions with professional staffs. By the decade's end, amateur researchers found themselves effectively sidelined by their institutional brethren.

Then as now, disagreements among astronomers over physical theories, working methods, and interpretation of data were routine, whether through correspondence, at conferences, or in the pages of research journals. But of all the disputes during this period, by far the longest and most fractious was the battle between two pioneers of celestial photography: Isaac Roberts, a wealthy English amateur, and Edward Emerson Barnard of the Lick and Yerkes observatories. Their exchange spawned a debate over the nature of diffuse nebulae that would roil the ranks of astronomy for nearly a decade.

The Welsh-born Isaac Roberts had made a fortune in the construction business, and he applied his wealth toward an ambitious program in celestial photography. His observatory at Crowborough, Sussex, was among the finest in Britain, housing a 20-inch f/5 Grubb reflector and a 7-inch Cooke refractor sharing a twin mount. Roberts took a celebrated four-hour exposure of the Andromeda Nebula that drew gasps at an 1889 meeting of astronomers, who were awed by its jaw-droppingly clear depiction of the mysterious space-cloud's spiral structure. Roberts published a two-volume photographic atlas of star clusters and "nebulae" (galaxies included) in 1893 and 1899. It was a testament to the tenacity with which he ranged over the celestial menagerie. He took nearly 2,500 astronomical plates during his lifetime. For his uncommon skill in rendering the cosmic landscape, Roberts was elected to the Royal Society, received an honorary doctorate from Trinity College, Dublin, and was awarded the Royal Astronomical Society's Gold Medal.

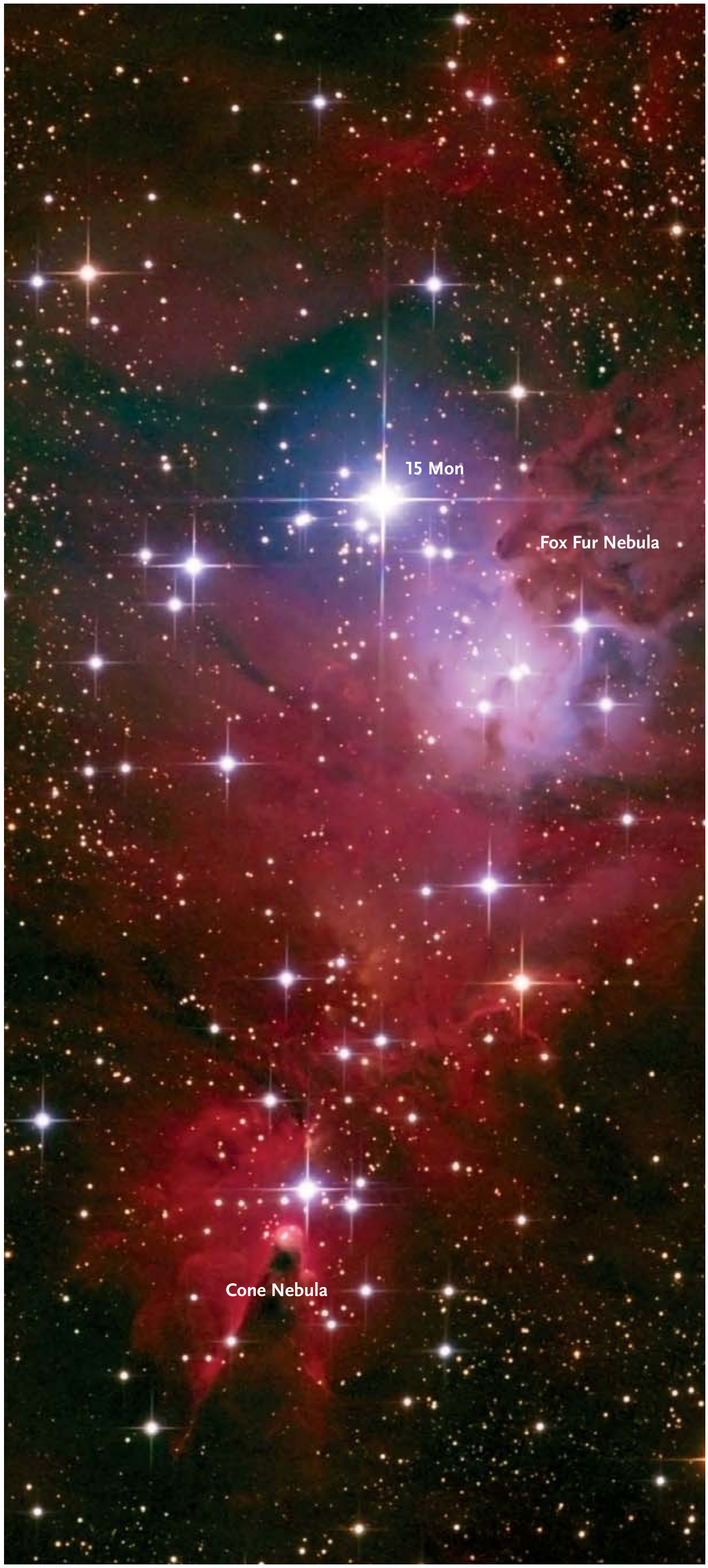
On May 10, 1895, Roberts stepped up to the lectern at a meeting of the Royal Astronomical Society. The audience was eager to witness the latest example of his photographic prowess. Roberts obliged by showing a lantern slide of his three-hour exposure of the starry nebular complex NGC 2264, which surrounds the 4.6-magnitude star 15 Monocerotis. Among the prominent features

ISAAC ROBERTS (1829–1904) was an immensely skilled and productive amateur who blazed deep-sky photography trails but ran aground on his inability to unlearn wrong ideas.

E. E. BARNARD (1857–1923), at far right, was a grade-school dropout but developed the technical skills and the scientific discernment to carry him through an illustrious career at Lick and Yerkes observatories.

ROBERTS: LICK OBSERVATORY / UC SANTA CRUZ; BARNARD: WIKIPEDIA / BILD-PD

MODERN CONFIRMATION **Today, backyard amateurs with modest gear far surpass the greatest astrophotographers of 120 years ago. Even without narrowband filters, the intricate clouds around 15 Monocerotis (S Monocerotis) and the Cone Nebula stand brilliantly revealed in Andrew Lecher's stack of 54 ten-minute exposures. He took 18 each through red, green, and blue filters. The frame is 1° tall, with north up. The upside-down Christmas Tree asterism spans most of the nebula, with 15 Mon as the tree's base and the bright star just north of the Cone Nebula as its tip.**



was a "conical dark space bounded by a rim of nebulosity" — the now-famous Cone Nebula — just south of a larger, triangular bevy of stars now named the Christmas Tree Cluster.

Roberts then projected a second lantern slide of the same region, this one from a glass photographic positive that had recently arrived from the United States. The photographer — Lick Observatory's Edward Emerson Barnard — was, like himself, a widely acknowledged expert in astronomical imaging. Although the pair of images depicted identical regions, they looked distinctly different. The stars in Roberts's photograph, taken with his 20-inch telescope, were virtual pinpoints. Those in Barnard's picture, taken with Lick's 6-inch, f/5.2 wide-field Willard camera, appeared as bloated disks.

Roberts acknowledged that he had enlarged Barnard's photograph fivefold to match the scale of his own. He had done so to make a point. The profuse "nebulosity" depicted in Barnard's image was illusory, he argued; it stemmed from the poor resolution of the Willard camera, which captured large swaths of sky at a highly compressed scale. Through his own 20-inch reflector, he said, the purported nebulous glows and swirls in the star cluster are seen for what they are: aggregations of faint stars, entirely beyond the feeble light grasp of Barnard's little instrument.

Unwittingly or not, Isaac Roberts had fired a transatlantic salvo from an amateur astronomer's station south of London into the heart of a professional research institution in California. The return volley from Barnard was not long in coming.

E. E. Barnard was the product of an impoverished, hardscrabble upbringing in Tennessee during the Civil War. He was a high-strung workaholic who had just two months of formal schooling before he took a job as a studio photographer's assistant at age nine. Barnard learned astronomy in his teens from Thomas Dick's popular handbook *The Practical Astronomer*. He became a passionate hunter of comets, discovering 16 of them altogether, and built a house for himself and his bride with the reward money that was offered at the time to comet finders.

In 1888, after a five-year stint as a non-degree student and observatory manager at Vanderbilt University, Barnard joined the staff of the new Lick Observatory in

California. It was here, in 1892, that he garnered worldwide recognition with his discovery of Jupiter's fifth and innermost moon, Amalthea.

Barnard began experimenting in wide-field celestial photography in 1889, six years before Isaac Roberts's unflattering display of his work. In the interim, he accumulated a series of extraordinary skyscapes with the Willard camera in guided exposures up to five hours long. The camera's achromatic doublet lens (refigured by the renowned Pittsburgh instrument maker John Brashear) was mounted in a simple wooden box and strapped to a 6½-inch guiding refractor (pictured at right). It produced photographic images of the Milky Way that, in Barnard's words, showed "for the first time, the vast and wonderful cloud forms, with all their remarkable structure of lanes, holes and black gaps and sprays of stars." On cold nights, he suited up in an "Esquimaux coat made of reindeer skin, and heavy rubber overshoes." When asked by one shivering guest how to keep warm, he deadpanned, "We don't." Barnard was easily riled — by poor sky conditions, bureaucratic bungling, or as most recently lodged by Isaac Roberts, wrongful criticism of his work.

E. E. BARNARD, *A PHOTOGRAPHIC ATLAS OF SELECTED REGIONS OF THE MILKY WAY*

GOING DEEP IN MONOCEROS **Barnard's plate of the Milky Way in northern Monoceros, made with a 6-inch studio portrait lens, showed nebulosity all around the star cluster NGC 2264 (center), the Christmas Tree Cluster including 4.6-magnitude 15 Monocerotis. This section of the plate is 7° tall.**

Framing and Surface Brightness

In his written response to Roberts, which was read before the Royal Astronomical Society on November 8, 1895, Barnard complained, "It is unjust to use an enlargement such as Dr. Roberts used, because it necessarily puts these pictures at a disadvantage. My picture [of the Christmas Tree Cluster region] was simply spoiled by this, while Dr. Roberts' retained its original qualities, not being enlarged." The diaphanous cloud that stands out distinctly in Barnard's original, 10°-tall image appears only as a subtle field-brightening across the 2° plates from Roberts's 20-inch reflector. When imaged in a wide field that surrounded it with darker sky for comparison, Barnard insisted, the nebulosity left no doubt that it was actual diffuse matter and not the light of unresolved stars. "All that is wanted to show it fairly well with his reflector is a somewhat longer exposure and a larger plate to give more sky around it for contrast."

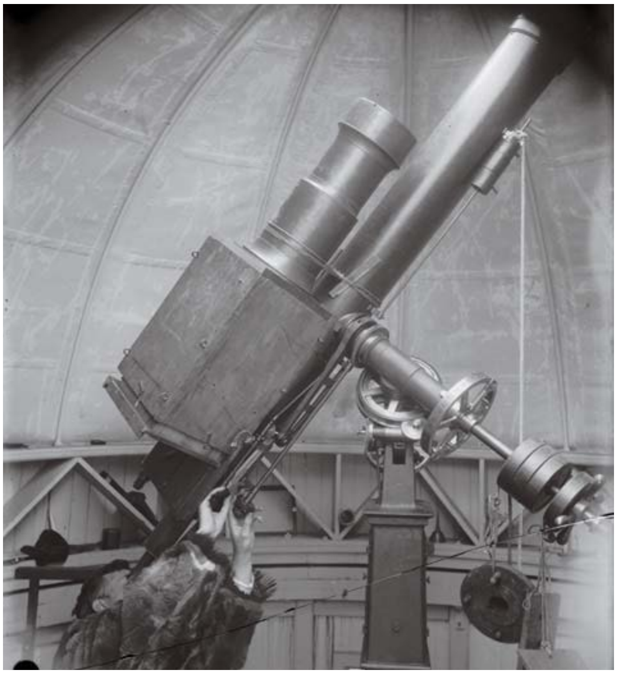
Barnard went on to emphasize an aspect of photography that Roberts had failed to grasp. True, a 20-inch telescope has more light-gathering power than a 6-inch camera lens, and it will record fainter stars. But unlike a point star, a diffuse nebula is spread out. What matters is its *surface brightness*: its light per unit area of sky, and per square millimeter on a photographic emulsion. A large-aperture telescope renders an interstellar cloud no brighter, in terms of surface brightness, than a small-aperture scope with the same f/ratio. Also important are sky transparency, exposure time, plate sensitivity — and a field wide enough to frame a very dim large object in a darker surround.

Barnard included three additional wide-field prints of the 15 Monocerotis–Cone Nebula region, demonstrating, in his opinion, "that Dr. Roberts' reasoning is decidedly wrong. This diffused light is in nowise confined to the star areas. It will be also readily seen that it spreads over a large region where there are essentially no stars at all — even where Dr. Roberts' reflector can show no stars. That this is real diffused nebulosity there is no reason whatever to doubt."

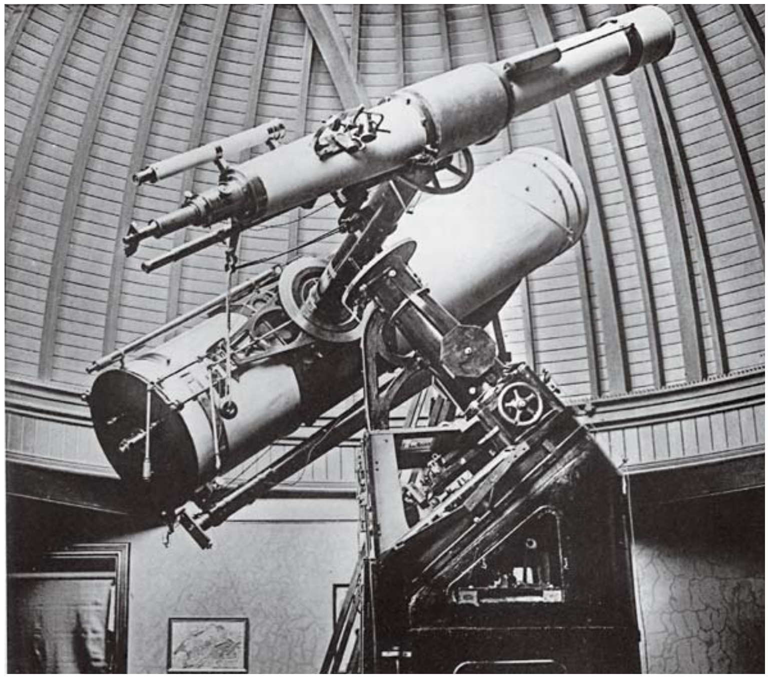
But Roberts refused to yield: a large-aperture telescope picks up fainter stars and therefore, he asserted, was able to reveal fainter nebulosity — which, as his photographs showed, was not there.

A Sinking Ship

Barely had the dust settled than a second battle erupted, this time over the presence of extended nebulosity around the Pleiades. Barnard had taken wide, four- and ten-hour exposures of the Pleiades and their neighborhood. These



LICK OBSERVATORY / UC SANTA CRUZ



ISAAC ROBERTS, *A SELECTION OF PHOTOGRAPHS OF STARS, STAR-CLUSTERS AND NEBULAE*

POWER PAIRS ***Left:*** **Barnard, in his "Esquimaux coat," guides on a star as he peers through Lick Observatory's 6½-inch Clark refractor and adjusts its fine-motion wheels. Riding on the refractor is the wide-field Willard camera with its 6-inch portrait lens. Barnard sometimes guided an exposure for five hours at a stretch.** ***Right:*** **With his 20-inch reflector and 7-inch refractor on a dual equatorial mount, Isaac Roberts ran one of the finest private observatories in England. But the large image scale of the big scope made it ineffective for large, diffuse nebulae with low surface brightnesses.**

captured not only the cluster's internal wisps but dim, diffuse arcs extending out. At the April 1896 meeting of the British Astronomical Association, Roberts argued that the arcs were merely "circles of halation" caused by defects or reflections in Barnard's lens. Furthermore, they did not appear in his own exposures using a 5-inch wide-field camera that he had recently installed.

A testy Barnard dashed off a note to the Royal Astronomical Society, suggesting that the "previous experience of Dr. Roberts with the diffused and faint nebulosity about 15 Monocerotis . . . might warrant some hesitation on his part in denying the existence of a similar region about the Pleiades."

Barnard followed up on October 22, 1898, with an announcement to the Royal Astronomical Society that Herbert C. Wilson at Carleton College in Northfield, Minnesota, and Solon I. Bailey at Harvard had both recorded images of the supposedly fictitious nebulosity around the Pleiades. Barnard didn't mention Roberts by name, but it's clear where his invective was directed: "These nebulosities . . . have been amply verified (if such a verification were at all necessary). . . . It would therefore appear that a failure to show these remarkable features with an ordinary portrait lens and an exposure [well short of] 4 or 5 hours must be attributed to something else than their non-existence."

By now the weight of opinion favored Barnard. The Royal Astronomical Society had published more than two dozen of his papers and awarded him its Gold Medal. Two other trailblazers of deep-sky photography, Andrew Common and David Gill, openly disputed Roberts's ideas about nebular imaging. An 1898 review by astronomer R. A. Gregory, at Queens College, London, lavished praise on the wide-field camera as an astronomical instrument. In what he termed the "warm controversy" between Barnard and Roberts, Gregory fully endorsed the reality of the nebulous clouds on Barnard's plates.

Several years passed. The final parry between Roberts and Barnard occurred in 1903 in the pages of the *Astrophysical Journal*. Roberts had submitted an article on William Herschel's visual catalog of faint, extended nebulosity. Over the previous six years, Roberts had photographed all 52 of Herschel's faint nebular regions with both his 20-inch reflector and wide-field camera, yet found nebulosity in only four. Evidently, one of history's keenest visual observers had imagined all the rest.

So extraordinary was this claim that the journal's editors engaged Barnard, now at Yerkes Observatory, to write a rebuttal. The articles appeared together.

Barnard pointed out that Roberts's exposure time of 90 minutes was too short to show very faint interstellar clouds; his own camera shutter typically remained open for four or five hours. As one might tutor a neophyte, he reiterated the primacy of surface brightness for nebular visibility. To illustrate the point, he described a picture he had taken of Herschel's Region 27 in Orion through an ordinary lantern-slide projector lens a mere 1.6 inches across: "Most of the great curved nebula is clearly

ROGELIO BERNAL ANDREO / DEEPSKYCOLORS.COM

ORION HEAD TO TOE The vast arc of Barnard's Loop encircles Orion's Belt and Sword in this extremely deep image stack taken by Rogelio Bernal Andreo. Amateurs dominate wide-field astrophotography today.

shown," he wrote of the huge, ghostly arc now known as Barnard's Loop, "especially the region described by Herschel. . . . There is therefore no question but that this nebulosity exists where Herschel saw it."

In closing, Barnard thrust a dagger at Roberts's competence, reminding readers that it was "with the same instruments described in his present paper that Dr. Roberts failed to get any trace of the exterior nebulosity of the Pleiades, which had been shown by four observers with four different instruments not only to exist, but to be not at all difficult objects."

Moreover, Max Wolf at the University of Heidelberg had recently taken a wide-field image of the same Region 27 using Heidelberg's new 16-inch astrograph. The picture showed, with remarkable clarity, not only the familiar Orion Nebula and the diffuse Horsehead complex around Zeta Orionis, but also the feathery, winding form of Barnard's Loop.

Where, 15 years earlier, Isaac Roberts had astounded astronomers with his breakthrough image of the Andromeda Nebula, he was now confronted with an equally vivid portrait of a celestial object that he claimed wasn't there. The Heidelberg 16-inch was neither the "small toy" nor "child's lantern-lens" that Roberts had called Barnard's instrument. And Wolf's exposure time of 6¼ hours eclipsed Roberts's own 90-minute standard. (Wolf's *pièce de résistance* would come in 1911 with a 24-hour exposure of the Andromeda Nebula's spectrum, accumulated over twenty nights.)

Roberts offered the weak suggestion that both Wolf and Barnard had targeted the wrong object! If not that, then maybe the apparition on their plates had arisen from atmospheric glare or reflections in the optics. Had he accepted the verdict of his own eyes, he would have recognized that a 90-minute exposure under moist, semi-transparent English skies might indeed be insufficient to capture a low-contrast space cloud, especially when it overran the border of his plate. He clung to the misconception that if he exposed long enough to capture the faint stars William Herschel had seen, then Herschel's faint clouds should appear as well. In fact, Barnard announced that he did see traces of extended nebulosity on Roberts's plates, a claim Roberts himself denied.

The nebular feud ended abruptly with Isaac Roberts's death in 1904.

This episode is often remembered for how it symbolized astronomy's widening professional-amateur divide around the turn of the 20th century. But the real meaning is a bit different. Barnard, a self-taught grade-school dropout, was something of an *über*-amateur himself. Rather, the skirmish and its outcome reflected astronomy's move toward professionalization and more rigorous scientific standards. In his drive to become an effective researcher, Barnard aligned his working methods and critical judgment to those of university-trained astronomers. His knowledge base was largely empirical, but it was structured effectively, in a way one learns in the halls of academia. When Barnard criticized Isaac Roberts for calcified thinking, for not keeping up with the technical literature, and for shrugging off big gaps in his knowledge, he was enumerating the hallmarks of a poor scientist. That Roberts was an amateur was not the issue.

Today, E. E. Barnard and Isaac Roberts are invariably linked to the photographic catalogs they bequeathed to astronomy. Despite Barnard's victory over Roberts in their long public feud, neither catalog stands higher than the other. Both are examples of the era's highest scientific artistry. Image scale was the difference: where Barnard portrayed the broad skylines of the galactic metropolis, Roberts captured the façades of its notable individual structures — two astronomers, no longer at odds, but complementing each other. ✦

Alan Hirshfeld *is a professor of physics at UMass Dartmouth, an associate of the Harvard College Observatory, and a historian of astronomy. His most recent book is* Starlight Detectives: How Astronomers, Inventors, and Eccentrics Discovered the Modern Universe.

This 4-hour total LRGB exposure made with an 80-mm refractor highlights the dusty reflection nebula surrounding the bright stars of the Pleiades (M45).

In This Section

PHOTOGRAPH: ZORAN NOVAK

Additional Observing Story:

OBSERVING

Sky at a Glance

JUNE 2016

3 DAWN: The very thin crescent Moon hangs about 2° below Mercury as seen from North America; binoculars may help you spot them barely above the eastern horizon 20 or 30 minutes before sunrise. Mercury is a modest magnitude +0.6.

2–3 ALL NIGHT: Saturn reaches opposition tonight. This month the Ringed Planet, well-lit by the Sun, shines throughout the night in Ophiuchus.

9 EVENING: Look about 7° above and left of the waxing crescent Moon to find Regulus, the brightest star in Leo.

10 EVENING: The Moon rests about halfway between Regulus and the distinctly brighter Jupiter.

11 EVENING: The Moon, approaching first quarter, forms a triangle with Jupiter and much dimmer Sigma (σ) Leonis.

14 EVENING: First-magnitude Spica shines less than 5° below the waxing gibbous Moon.

17–18 ALL NIGHT: The Moon, Saturn, and Mars make a wide, flat triangle, with the longest side stretching about 18° to connect the two planets.

18–19 ALL NIGHT: The Moon and Saturn are 3° to 5° apart tonight. After dusk, look below and right of the pair to spot Antares, the supergiant at the heart of Scorpius.

20 THE LONGEST DAY of the year in the Northern Hemisphere. Summer begins at the solstice, 6:34 p.m. EDT.

Planet Visibility

SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH

	◀ SUNSET	MIDNIGHT	SUNRISE ▶
Mercury	Visible June 7 through June 24		NE E
Venus	Hidden in the Sun's glare all month		
Mars	SE	S	SW
Jupiter	SW	W	
Saturn	SE	S	SW

Moon Phases

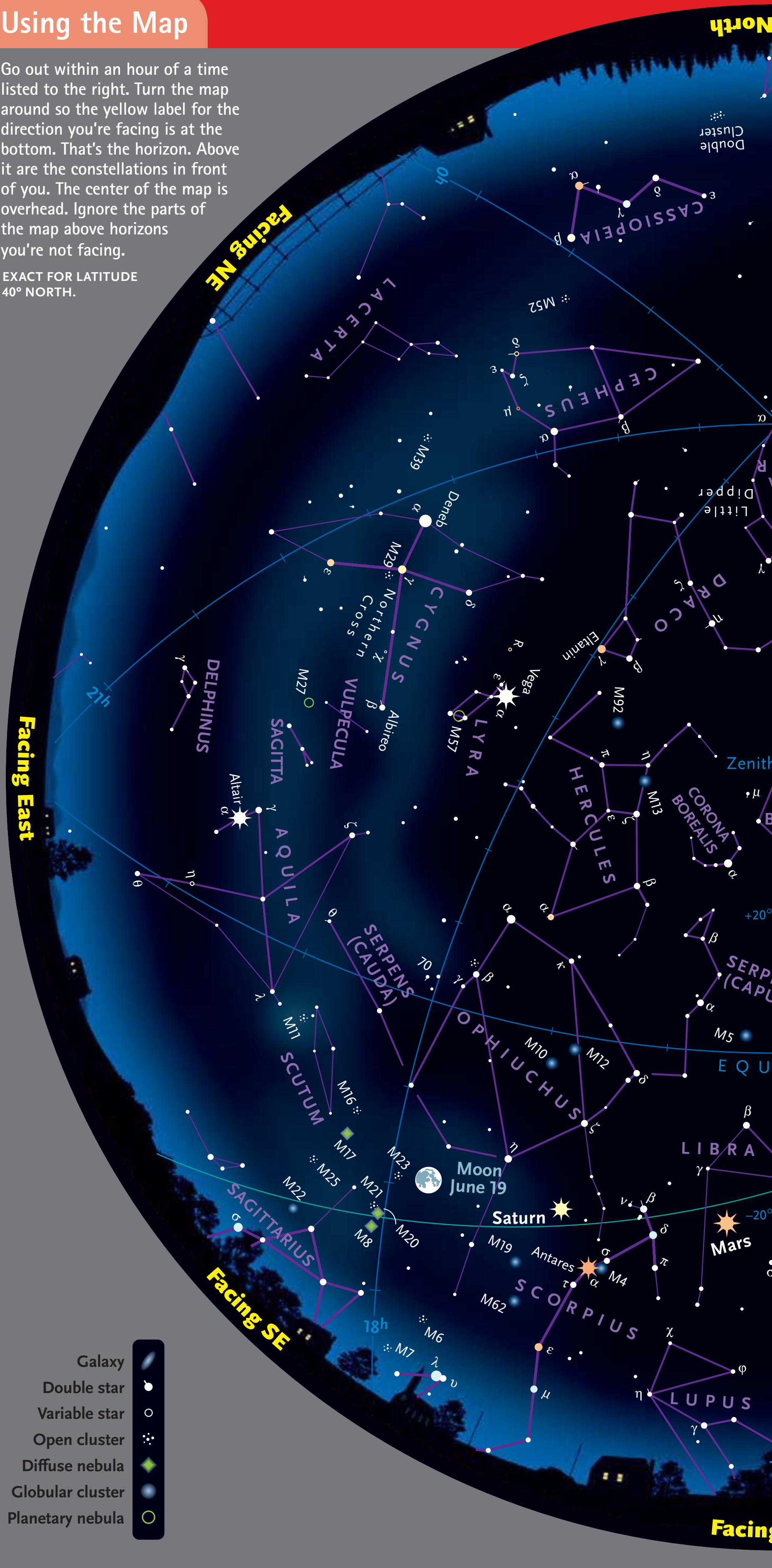
New	June 4	11:00 p.m. EDT	
First Qtr	June 12	4:10 a.m. EDT	
Full	June 20	7:02 a.m. EDT	
Last Qtr	June 27	2:19 p.m. EDT	

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		

Using the Map

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

EXACT FOR LATITUDE 40° NORTH.



Galaxy
Double star
Variable star
Open cluster
Diffuse nebula
Globular cluster
Planetary nebula

When

Late April	2 a.m.*
Early May	1 a.m.*
Late May	Midnight*
Early June	11 p.m.*
Late June	Nightfall

*Daylight-saving time.

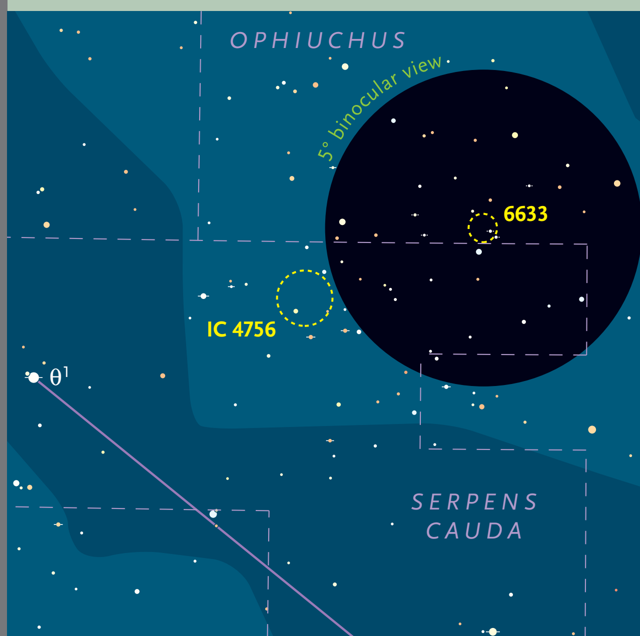
A Starry Shoe

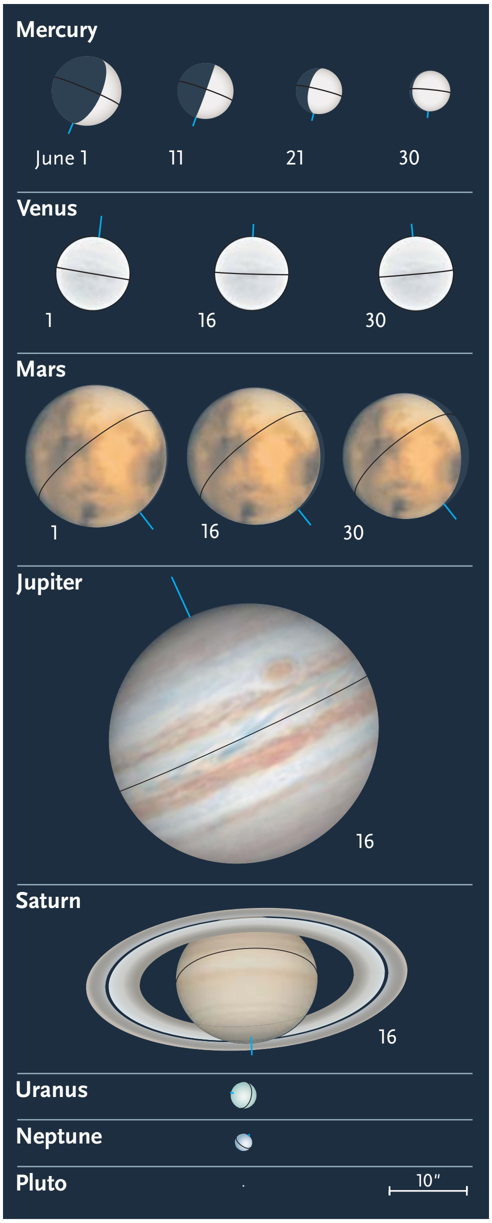
A lot of stargazers don't observe exclusively with either binoculars or a telescope, but switch back and forth as needed. There's a lot to be said for examining the same target with different instruments.

I was reminded of this when I revisited **NGC 6633**, an open cluster in the eastern reaches of Ophiuchus. When I was a newcomer to astronomical sketching, this cluster was one of my first targets. Only later did I learn its nickname: the Italy Cluster. Some years ago, Michele Bortolotti and Guido Rocca of Verona, Italy, pointed out that NGC 6633 was reminiscent of their home country's famous "boot" shape. Because I'd used a reflector, my sketch was inverted. When I turned the drawing around, Italy's shape was not just obvious, it was unavoidable. There's even a stellar Sicily anchored on the 5th-magnitude foreground star HD 170200.

When I visited the area on a pre-dawn binocular hunt, I was delighted to see the Italy shape of NGC 6633 was readily apparent in my 10×50 binoculars. Maybe I should have anticipated that — with a maximum extent of nearly ½° and a magnitude of 4.6, the cluster is big and bright enough to show considerable detail in binoculars. For a challenge, see how many stars you can resolve. At a distance of 1,200 light-years, most of the cluster's 150-plus members merge into a nebulous glow, leaving only a dozen or two of the brightest blazing in the foreground.

Most guides include NGC 6633 in a band with IC 4665 and IC 4756. But I have other homework for you: pick out the stream of faint suns, about 1° wide, which runs north from NGC 6633 before breaking into several chains of stars, like branches from the trunk of a tree, near the border with Hercules. ✦



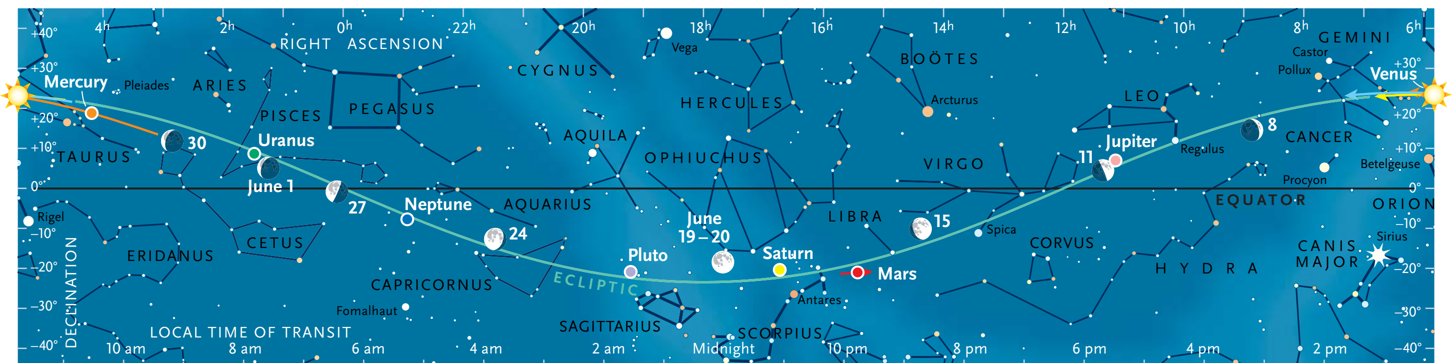


Sun and Planets, June 2016

	June	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	4^h 36.5^m	+22° 03′	—	–26.8	31′ 33″	—	1.014
	30	6^h 36.6^m	+23° 10′	—	–26.8	31′ 28″	—	1.017
Mercury	1	3^h 04.1^m	+13° 24′	24° Mo	+0.8	9.0″	29%	0.745
	11	3^h 42.5^m	+16° 36′	23° Mo	0.0	7.3″	49%	0.926
	21	4^h 44.0^m	+20° 56′	18° Mo	–0.7	6.0″	73%	1.126
	30	5^h 59.2^m	+23° 48′	9° Mo	–1.5	5.3″	94%	1.275
Venus	1	4^h 29.8^m	+21° 35′	2° Mo	–4.0	9.6″	100%	1.734
	11	5^h 22.5^m	+23° 19′	1° Ev	—	9.6″	100%	1.735
	21	6^h 16.1^m	+23° 56′	4° Ev	–3.9	9.6″	100%	1.730
	30	7^h 04.4^m	+23° 28′	6° Ev	–3.9	9.7″	99%	1.720
Mars	1	15^h 42.4^m	–21° 22′	167° Ev	–2.0	18.6″	99%	0.503
	16	15^h 24.8^m	–20° 59′	149° Ev	–1.7	17.9″	97%	0.524
	30	15^h 18.9^m	–21° 00′	134° Ev	–1.4	16.4″	93%	0.569
Jupiter	1	11^h 02.2^m	+7° 34′	93° Ev	–2.1	37.3″	99%	5.291
	30	11^h 13.0^m	+6° 21′	68° Ev	–1.9	34.4″	99%	5.737
Saturn	1	16^h 47.5^m	–20° 34′	177° Mo	0.0	18.4″	100%	9.016
	30	16^h 38.8^m	–20° 21′	153° Ev	+0.1	18.2″	100%	9.118
Uranus	16	1^h 28.0^m	+8° 34′	62° Mo	+5.9	3.5″	100%	20.424
Neptune	16	22^h 54.2^m	–7° 55′	103° Mo	+7.9	2.3″	100%	29.707
Pluto	16	19^h 10.8^m	–21° 01′	159° Mo	+14.1	0.1″	100%	32.170

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

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



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

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

Fred Schaaf

The Seal of the Sky

The patterns we draw in the sky capture our hopes and ancient dreams.

Crystal and the clay, nights and the day
All on the prince's seal
Eagle of the sky, lion of the earth
This is what the seal is worth, what the seal is worth
Holds all of the dreams of a man
Tapestries, wishes of man, pictures and visions of man
The spirit, the soul of the man
And he would vow to love her for the rest of all his days.
— Michael Dunford and Betty Thatcher, *The Young Prince and Princess*

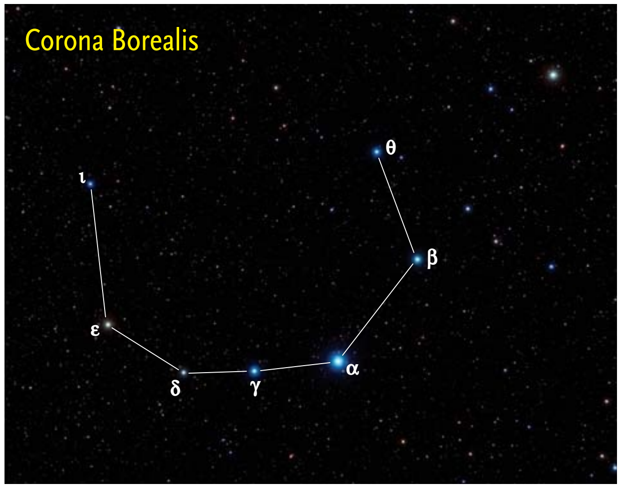
I used another quote from this lovely song in the April column, when I discussed the ways, practical and mystical, in which a starry sky is the dwelling-place of "a thousand secret flames." But here, I want to use it to compare the sky of June evenings to something else: "the prince's seal."

After June sunsets in much of the Northern Hemisphere, the secret presence of the stars — we need to remind ourselves they're always there, even during our daytimes! — is revealed ever so slowly as the long solstice twilight fades. But as the stars finally come into view, we're confronted with not just their raw natural beauty, but also their roles as cultural markers. We're seeing them in a sky that's been engraved and re-engraved with complex patterns of both scientific and mythological organization. The night sky reflects the mind of humans. Another way to think of the starry sky is as a melting pot of fact, lore, story, and history.

Summer's starry emblems of eternity. From even the earliest era of human history, people must have pictured figures, mostly humans and animals, in the patterns of the stars and told stories about them. Part of the purpose of doing so was no doubt to eternalize the most important human experiences — love, death, fear, hope.

How wonderful it is that some of our greatest stories have survived thousands of years, not just on the basis of their own never-ending relevance to the human condition, but by being attached to the stars.

Three great multi-constellation myths were discussed in last October's installment of this column: the Greek myth of Perseus; the eastern Asian tale of the Weaving Maiden and the Cowherd (or Prince); and the Native American legend of the hunters who chase and, in autumn, wound the bear (the bowl of the Big Dipper).



AKIRA FUJII

These stories feature different constellations and asterisms. But throughout history, people have connected the same stars to form different patterns in their stories. For instance, June's prominently visible Corona Borealis, known as the crown of Ariadne, has also been imagined as the flying, revolving glass castle Caer Sidi, a spider, a boomerang, a broken circle of dancing maidens, and the lair of the bear.

And pattern-making in the summer sky hasn't stopped. It's remarkable, but the now-famous Summer Triangle of Vega, Altair, and Deneb, introduced in the 19th century, was only popularized a little more than 50 years ago. And the "Teapot" asterism of Sagittarius, which now seems so obvious to everyone, was created even more recently.

What's ironic is that even our longest-enduring myths and legends are like the latest ripples in a pool compared to the lifetimes of the stars themselves. Even the stars don't last forever — but these shining lights that live for billions of years are the closest thing to true eternity that we can ever see.

The seal of the sky. Look at those lyrics again. The only "seal" I can think of that can hold all of the dreams, wishes, pictures, and visions of humans is the sky. Our constellations are its engravings. "Eagle of the sky, lion of the earth": Leo the Lion is coming back down to Earth, sinking to the western horizon, on June evenings, while Aquila the Eagle, rising from the eastern horizon, is lifting up to the sky. ✦

Three Planet Night

Jupiter, Saturn, and Mars shine in the dark, Mercury peeks up at dawn.

Three bright planets adorn the sky at June's late nightfalls this year. At dusk, Jupiter shines in the southwest, while Mars gleams in the southeast to south. Saturn rises moderately far behind Mars. Dependably bright Jupiter sets at midnight by month's end. Just past opposition and its closest to Earth, the still blazingly bright Mars is highest in the south a few hours after sunset. Golden Saturn, east of Mars, reaches opposition in early June and therefore is visible from dusk to dawn for much of the month. Mercury can be glimpsed very low in the east-northeast at dawn.

DUSK THROUGH EVENING

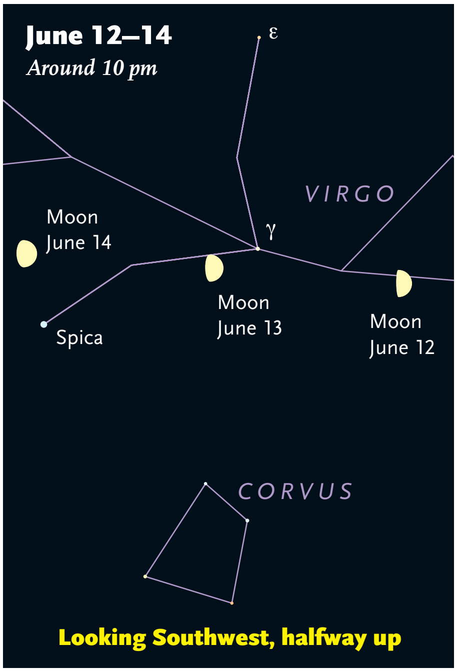
Jupiter dominates the southwest and western sky all evening. At the start of June, Mars almost equals it in brightness, but during the month Mars fades significantly while Jupiter only dims from magnitude –2.1 to –1.9. Jupiter's disk shrinks from 37″ to 34″ wide and should be observed as early at night as possible before it starts dropping low in the west. Jupiter's setting time backtracks from before 2 a.m. by June 1st to midnight on June 30th. Jupiter reaches eastern quadrature (90° east of the Sun) on June 4th, so throughout the month the shadows of the planet and its moons are cast farthest to the east as seen from our point of view.

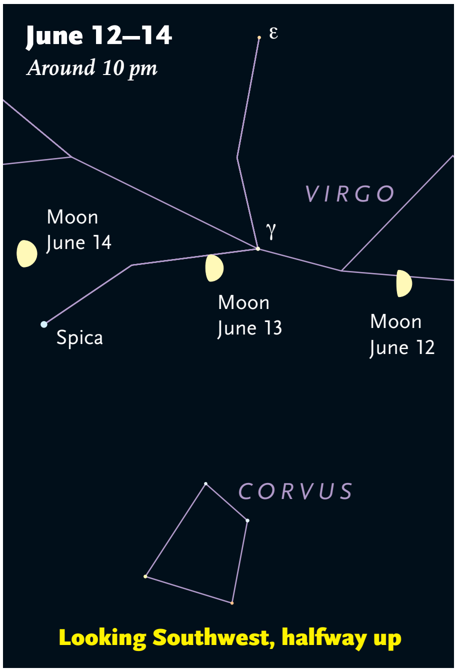
Another sight to look for is a star masquerading as a slightly brighter, out-of-place Galilean satellite. Chi (χ) Leonis was only 7′ south of Jupiter back on April 8th. On June 10th, it passes about 5½′ north of Jupiter.

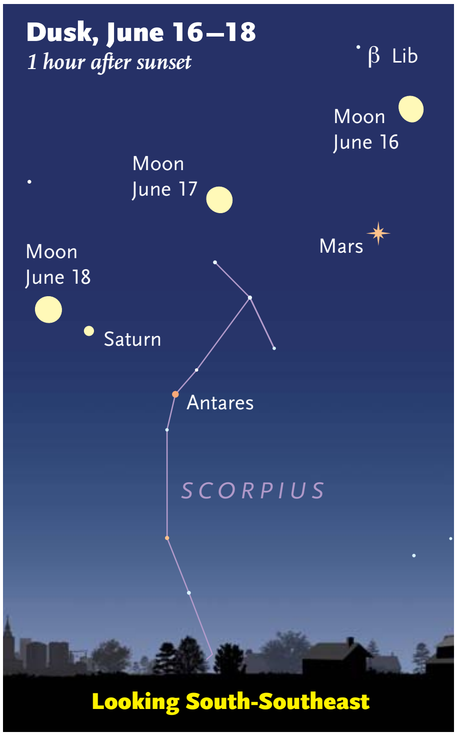
DUSK TO DAWN

Mars reached opposition on May 22nd and on May 30th came its closest to Earth in 11 years. Enjoy its formidable tiger-colored stare while it's still very bright — for Mars now begins to fade rapidly. Starting June at magnitude –2.0, Mars dims to –1.5 by month's end. As faster Earth begins to leave its outer neighbor behind, the apparent size of Mars's globe diminishes. Its diameter dwindles from 18½″ to 16½″ across this month — but even the latter figure is still larger than Mars has appeared for a decade. See our April issue, page 48, for full details on observing Mars through the telescope during this fine apparition.

As June progresses, Mars reaches the meridian earlier, aiding observers in their pursuit of a good view. The higher Mars is, the sharper its image is likely to appear in the eyepiece. Mars culminates (stands highest on the meridian) around midnight as the month begins but not long after 9:30 p.m. (when most of us are still seeing strong twilight) as June ends.

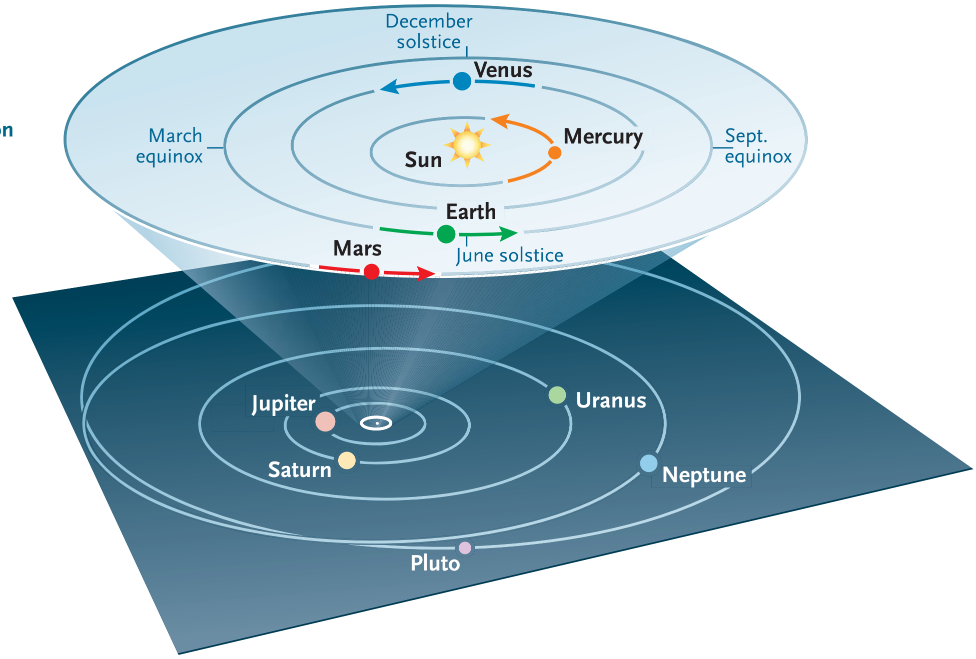






ORBITS OF THE PLANETS

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



Helping Mars rise to the meridian even earlier is its retrograde motion, which carries it westward and deep into Libra this month. However, as Earth rounds its orbit, our perspective changes. The Red Planet halts its retrograde motion on June 30th, then begins direct (eastward) motion against the background of stars. After this, Mars picks up apparent speed and begins to close the now sizable gap between itself and the following planet — Saturn.

Saturn reaches opposition on June 3rd, when its somber golden glow shines at magnitude 0.0 in Ophiuchus. While Mars has sprinted ahead from Ophiuchus and Scorpius, Saturn still hangs over the back of the Scorpion, attractively paired with Mars-colored (but only 1st-magnitude) Antares, some 7° below it or to its lower right.

Saturn climbs to the meridian 1 to 1½ hours after Mars this month. That's the time to look for the steadiest, sharpest views of its 18″-wide globe and its 42″-wide rings. The rings tilt a generous 26°, nearly as open as we can ever see them, so they contribute almost a magnitude's worth of brightness to Saturn's glow.

Pluto, about 14 magnitudes dimmer than Saturn, will be at opposition on July 7th. We'll have a finder chart in next month's issue.

DAWN

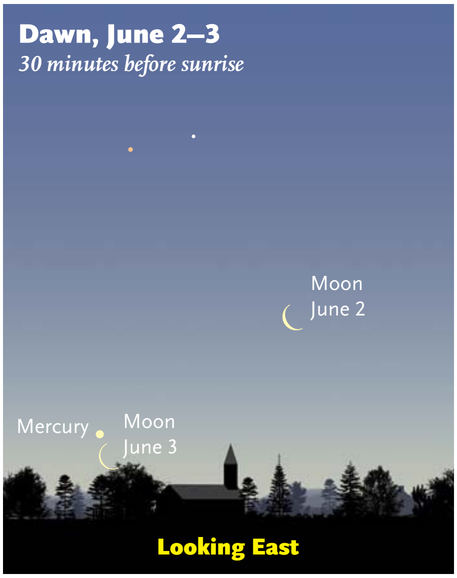
Mercury brightens rapidly in the first days of June and is barely visible at greatest elongation on June 5th. It's highest for observers around latitude 40° north about a week later, on June 12th — when its magnitude has brightened to 0.0. Even then, however, viewers at mid-northern latitudes will find Mercury only about 7° high in the brightening light 30 minutes before sunrise.

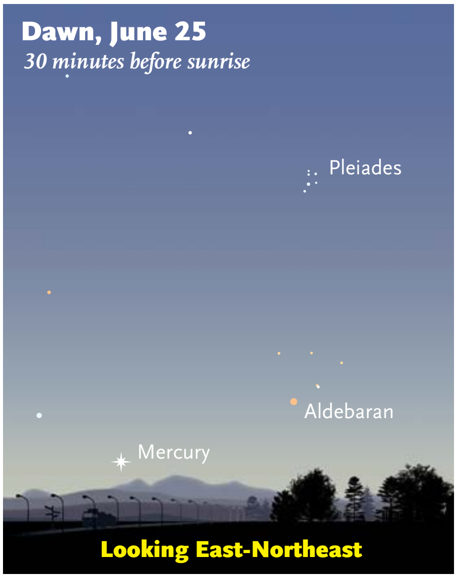
Venus is at superior conjunction with the Sun on June 6th and so is unobservable this month. **Uranus** and **Neptune** are highest at dawn, but still not very well placed for observation.

SUN AND MOON

The **Sun** arrives at the June solstice at 6:34 p.m. EDT on June 20th, marking the beginning of summer in the Northern Hemisphere and winter in the Southern Hemisphere.

The **Moon**, with dim Mercury just above it, is a thin crescent a few degrees above the horizon 30 minutes before sunrise on June 3rd. The first-quarter Moon shines to the left of Jupiter on the evening of June 11th. On the evening of June 14th, the waxing gibbous Moon is above Spica. On the 16th the Moon is well above Mars, and on the next evening about equidistant (but pretty distant indeed) from Mars and Saturn. On June 18th, the Moon is left or upper left of Saturn. ✦





Hunt the Moons of Mars

With Mars now big and close, try for Phobos and Deimos.

The closest planetary moons to Earth, after our own familiar Luna, are Phobos and Deimos orbiting Mars. Most amateurs have never seen them. In late May and early June, with Mars in its close approach to Earth, you have your best shot at them in 11 years.

The problem with seeing them in a telescope isn't that they're too dim. You might think they'd be fairly easy, since they shine at magnitudes 11.4 and 12.5, respectively, in the week or two around Mars's May 30th closest approach. (Mars and its moons are a half magnitude fainter at the beginning of May and by end of June.) The problem is that they orbit close to Mars amid its dazzling glare. Mars blazes 230,000 and 600,000 times brighter than Phobos and Deimos, respectively.

I've been able to see Deimos quite distinctly with my 12.5-inch reflector at good oppositions in the past. But I've never definitely succeeded with Phobos, which never gets more than about a third as far from Mars as Deimos does.

You'll need to use some tricks. The first is to choose the right time to look. You'll want to observe when one of the satellites is at one of its greatest elongations: at its farthest Mars. The elongations currently happen to the planet's northwest or southeast, as shown in the orbit diagram on the top of the facing page. Find a convenient elongation time at **http://is.gd/phobosdeimos2016**, where timetables are reproduced from the 2016 *Astronomical Almanac*. Phobos completes a full orbit every 7.6 hours, Deimos every 30.2 hours.

Or, in a good sky-mapping program, you can lock on Mars, zoom way in on it, and then run the time forward and backward to see when Phobos and Deimos reach their elongations.

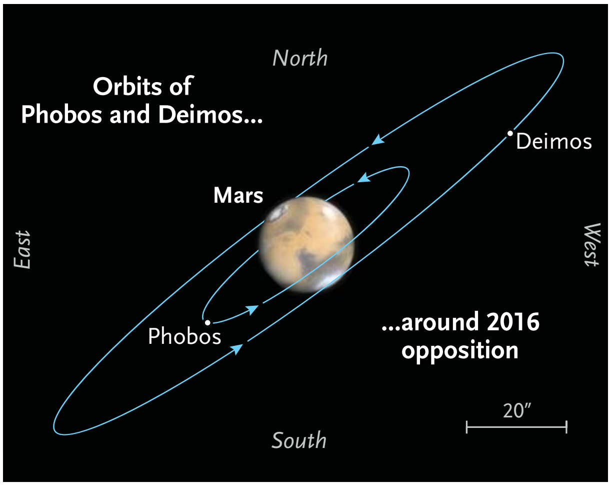
Next: make sure your eyepieces are clean as can be. Dust on your main mirror matters less because it's farther from your eye (meaning scattered light from the dust has more places to go that aren't into your pupil). But if you've been waiting for an excuse to clean your mirrors (gently!), this might be it.

In your highest-power eyepiece, add a temporary *occulting bar* across the center of the field so you can hide Mars behind it. The usual method is to unscrew the barrel, turn the eyepiece upside down, and tape a little strip of aluminum foil across the center of the round metal field stop, the open ring in the eyepiece's focal plane. Tweezers help. Then, looking in the eye end of the eyepiece, carefully use a pencil point to maneuver the foil strip into sharp focus.

The atmospheric seeing and the telescope's focus must be excellent if you want to see a faint pinpoint on a bright background. Collimate your mirror so the image will be as sharp as possible. And it may be best to use a faint star to set the fine focus, not the edge of Mars.

Unfortunately for northerners, Mars is fairly far south during this apparition (at declination –21° or –22° in May and June). So plan to observe when Mars is highest: around the middle of the night. And keep coming back night after night to increase your chance of catching a

James McGaha in Arizona took these images of Mars with tiny Deimos and Phobos on August 29, 2003, using a webcam on a 1-meter reflector atop Kitt Peak. To pick up the faint moonlets, McGaha had to vastly overexpose Mars (left), so he also made a composite using a short exposure of Mars (right) to show all three objects well.



Deimos never gets more than three Mars diameters from Mars's limb. Phobos always remains within just one. Try for them when they're at their northwest and southeast elongations.

time when the seeing is excellent. Watch for a prediction of good, steady seeing for your location up to 48 hours in advance using the Clear Sky Charts seeing forecast at **cleardarksky.com/csk/**.

At the eyepiece, take your time looking. Lots of time. Get comfortable; sit if you can. Use averted vision, with Mars behind the occulting bar. Once you glimpse your Martian moon, you'll glimpse it more readily thereafter.

Don't be fooled by an internal reflection! When you shift the telescope a little, that faint speck should move exactly the same as Mars does.

If you don't succeed, make a mental note for 2018. That summer Mars will grow to 24.3″ wide, compared to its 18.6″ late this May and early June. Phobos and Deimos will appear proportionately farther from the center of Mars, and all will be 0.8 magnitude brighter.

Mars Itself

As for that dazzling desert ball next to those perhaps invisible specks? Now is your chance to log some of the many famous surface features that have eluded you for years. One side of Mars is relatively bland and bright; the other is more mottled with darkish albedo features. The North Polar Cap is currently very small, and shrinking even further, in the late summer of the Martian northern hemisphere. If you see a lot of white near the southern limb of Mars, and if this is south of the great dark Syrtis Major, that's not the south cap (which is tilted slightly out of view) but clouds or frosts filling the large Hellas basin. To identify features, you'll need to know which part of Mars is facing you; use our Mars Profiler at **skyandtelescope.com/marsprofiler.** See our Mars map and detailed telescopic guide in the April *S&T*, page 48.

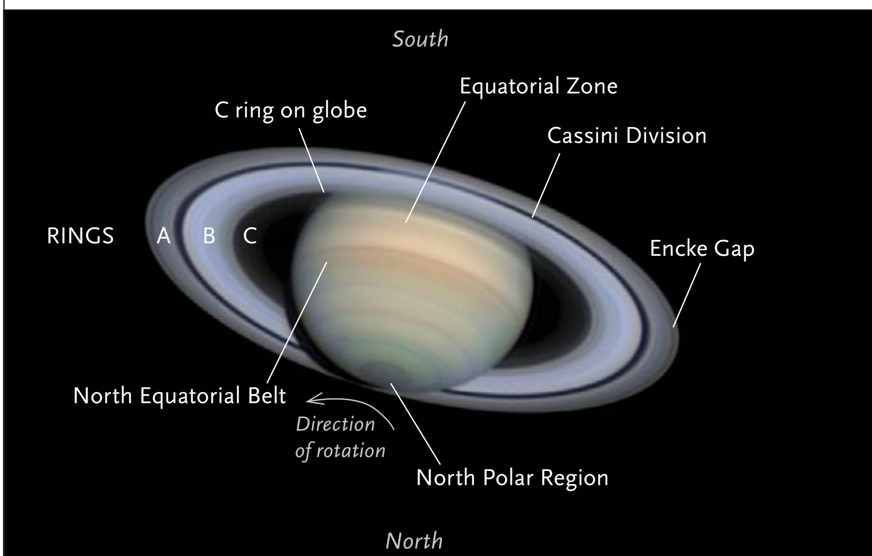
Saturn at Opposition

Saturn and Mars shine fairly close to each other in May and early June, hanging over the twinkly stars of Scorpius with Saturn to Mars's east. So it's no surprise that Saturn comes to opposition shortly after Mars does: on the night of June 2nd, following the May 22nd Martian opposition. If you're out with your scope for one of them, you'll surely spend time with both.

If Saturn looks brighter to the naked eye than you remember from a few years ago, you're right. Saturn's rings are now tilted a majestic 26° to our line of sight, almost as wide open as we can ever see them. So the rings reflect to us almost twice as much sunlight as Saturn's globe does. In a telescope, the rings now extend beyond both the north and south poles of Saturn, affording a clear view of their outer perimeter all around. This is only just barely the case in the image below, taken last year.

So it's a very good year to look for the finest possible details in the rings. Can you trace the dark Cassini Division all the way around? How apparent is the dusky C Ring close to the planet? It's semitransparent; look for its gray band against the planet's face inside the B Ring. And can you make out the C Ring's faint gray glow in the area where it's seen against the dark background of space?

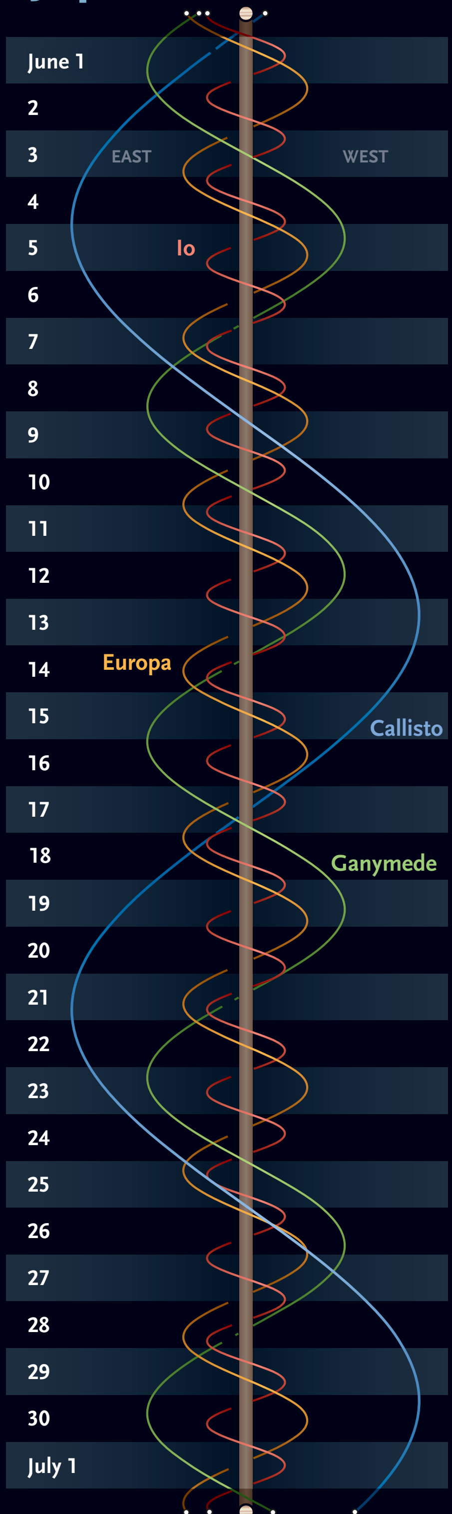
Notice the different levels of brightness across the B and A rings. Both are brightest next to the Cassini Division. When the seeing settles down to be especially still, can you see anything else going on? For a real challenge with a 12-inch or larger scope, can you detect the tiny hairline of



Saturn's rings were tilted 25°, almost as much as they are now, when Damian Peach took this very sharp image on March 10, 2015, using a planetary video camera on a 14-inch Schmidt-Cassegrain scope.

DAMIAN PEACH

Jupiter's Moons



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

the Encke Gap shimmering in the seeing at your highest power?

As opposition comes and goes, watch for the *Seeliger effect*: a brightening of the rings (but not the globe) for a few days, caused by the dusty ring particles backscattering sunlight toward the Sun. We intercept this backscattering when we are very close to the Sun-Saturn line around opposition. This same "opposition effect" also slightly brightens Mars and the full Moon. On a sunny day, you sometimes see it as a slightly brighter glow around the shadow of your head when your shadow falls on dusty material of the right texture.

The globe of Saturn itself is a more subdued version of Jupiter. You'll probably be able to see at least the bright Equatorial Zone and the darker North Equatorial Belt. Any more belts? A rare white spot? The tilt of the whole Saturnian system this year shows us the North Polar Region unusually well. Read more about Saturn observing in the June 2015 *S&T*, page 50.

Moons Galore

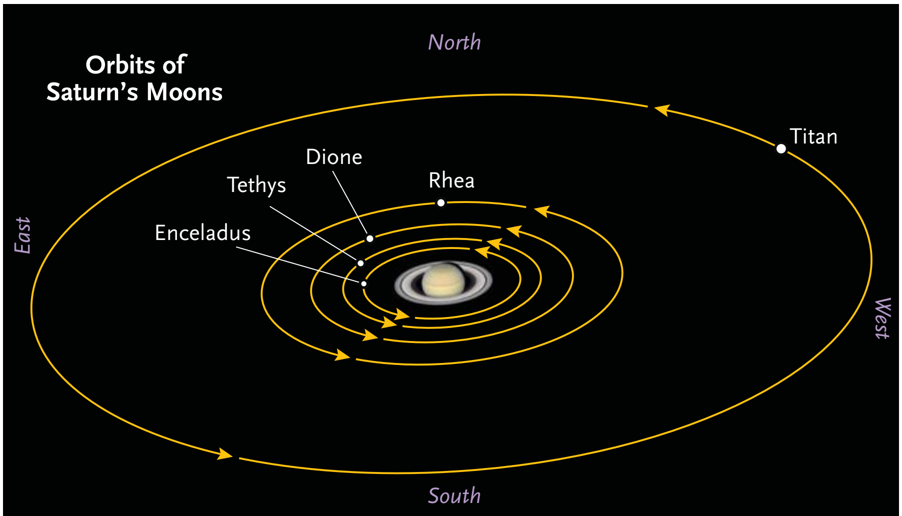
The planet with the obvious rings offers the most moons for amateur telescopes, and that's no coincidence. Rings and moons form out of an abundance of the same orbiting material. Over cosmic time, they can even morph from one into the other.

Take this opportunity to add to your life tally of moons you've observed. Titan shows up in a 3-inch scope, and a 4-inch may reveal the orange color of its thick atmosphere. A 4- or 6-inch will add Rhea, Dione, and (maybe with difficulty) Tethys. An 8- or 10-inch may get you Enceladus.

Weird Iapetus is not shown on the orbit diagram below. Its wide orbit keeps it mostly far outside the frame. Iapetus varies from an easy magnitude 10 when farthest west of Saturn to a darker magnitude 12 when farthest east. (Remember this by "East is least, west is best.")

Moons don't count toward your lifetime tally unless you can say which is which! Identify the ones you see, or locate in advance exactly where to look, using **skyandtelescope.com/satmoons** or our SaturnMoons app from the iTunes App Store. For Iapetus you'll need a full-up sky-charting program.

If you want to read more about building your lifetime tally of moons, see our article on this topic in the February 2015 issue, page 28. It builds on the familiar ones for amateur telescopes to add a truly challenging table of 20 more.



Big Titan, magnitude 8.4, takes 16 days to complete its wide orbit around Saturn. Little Enceladus, magnitude 11.8 and deep in the planet's glare, whips around the planet in just 1.4 days. Wide-ranging Iapetus is not shown.

June's Action at Jupiter

Although Jupiter is shrinking (from 37″ to 34″ across its equator this month) and descending in the southwest right after dusk, it's always an enticement for the telescope — especially this year with the Great Red Spot actually red and unusually easy to see, if you look when it's on the side of Jupiter facing us.

Jupiter's four big Galilean moons are visible in any scope. Identify them using the diagram at far left.

All of the June interactions between Jupiter and its satellites and their shadows are tabulated below.

And here are all the times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian. The dates, also in UT, are in bold.

May 1, 8:39, 18:35; **2,** 4:31, 14:26; **3,** 0:22, 10:18, 20:14; **4,** 6:09, 16:05; **5,** 2:01, 11:56, 21:52; **6,** 7:48, 17:44; **7,** 3:39, 13:35, 23:31; **8,** 9:26, 19:22; **9,** 5:18, 15:14; **10,** 1:09, 11:05, 21:01; **11,** 6:57, 16:52; **12,** 2:48, 12:44, 22:39; **13,** 8:35, 18:31; **14,** 4:27, 14:22; **15,** 0:18, 10:14, 20:10; **16,** 6:05, 16:01; **17,** 1:57, 11:53, 21:48; **18,** 7:44, 17:40; **19,** 3:36, 13:31, 23:27; **20,** 9:23, 19:19; **21,** 5:14, 15:10; **22,** 1:06, 11:02, 20:57; **23,** 6:53, 16:49; **24,** 2:45, 12:40, 22:36; **25,** 8:32, 18:28; **26,** 4:23, 14:19; **27,** 0:15, 10:11, 20:07; **28,** 6:02, 15:58; **29,** 1:54, 11:50, 21:45; **30,** 7:41, 17:37; **31,** 3:33, 13:29, 23:24.

June 1, 9:20, 19:16; **2,** 5:12, 15:07; **3,** 1:03, 10:59, 20:55; **4,** 6:50, 16:46; **5,** 2:42, 12:38, 22:34; **6,** 8:29, 18:25; **7,** 4:21, 14:17; **8,** 0:13, 10:08, 20:04; **9,** 6:00, 15:56; **10,** 1:52, 11:47, 21:43; **11,** 7:39, 17:35; **12,** 3:30, 13:26, 23:22; **13,** 9:18, 19:14; **14,** 5:09, 15:05; **15,** 1:01, 10:57, 20:53; **16,** 6:48, 16:44; **17,** 2:40, 12:36, 22:32; **18,** 8:27, 18:23; **19,** 4:19, 14:15; **20,** 0:11, 10:07, 20:02; **21,** 5:58, 15:54; **22,** 1:50, 11:46, 21:41; **23,** 7:37, 17:33; **24,** 3:29, 13:25, 23:20; **25,** 9:16, 19:12; **26,** 5:08, 15:04; **27,** 0:59, 10:55, 20:51; **28,** 6:47, 16:43; **29,** 2:39, 12:34, 22:30; **30,** 8:26, 18:22.

These times assume that the Great Red Spot is centered at System II longitude 234°. It will transit $1\tfrac{2}{3}$ minutes earlier for each degree less than 234°, and $1\tfrac{2}{3}$ minutes later for each degree greater than 234°. Features on Jupiter appear closer to the central meridian than to the limb for 50 minutes before and after they transit.

A light blue or green filter slightly increases the contrast and visibility of Jupiter's reddish and brownish markings. An orange filter helps darken the blues. ✦

Phenomena of Jupiter's Moons, June 2016

June 1	0:20	I.Tr.E
	1:34	I.Sh.E
	3:59	II.Tr.I
	6:08	IV.Ec.D
	6:34	II.Sh.I
	6:46	II.Tr.E
	8:10	IV.Ec.R
	9:17	II.Sh.E
	19:23	I.Oc.D
	22:56	I.Ec.R
June 2	16:34	I.Tr.I
	17:49	I.Sh.I
	18:49	I.Tr.E
	20:03	I.Sh.E
	22:14	II.Oc.D
June 3	3:30	II.Ec.R
	10:28	III.Tr.I
	13:48	III.Tr.E
	13:52	I.Oc.D
	15:39	III.Sh.I
	17:24	I.Ec.R
	18:47	III.Sh.E
June 4	11:03	I.Tr.I
	12:18	I.Sh.I
	13:17	I.Tr.E
	14:31	I.Sh.E
	17:17	II.Tr.I
	19:52	II.Sh.I
	20:04	II.Tr.E
	22:35	II.Sh.E
June 5	8:21	I.Oc.D
	11:53	I.Ec.R
June 6	5:31	I.Tr.I
	6:46	I.Sh.I
	7:46	I.Tr.E
	9:00	I.Sh.E
	11:31	II.Oc.D
	16:48	II.Ec.R
June 7	0:33	III.Oc.D
	2:50	I.Oc.D
	3:56	III.Oc.R
	5:48	III.Ec.D
	6:22	I.Ec.R
	8:58	III.Ec.R
June 8	0:00	I.Tr.I
	1:15	I.Sh.I
	2:15	I.Tr.E
	3:29	I.Sh.E
	6:36	II.Tr.I
	9:11	II.Sh.I
	9:23	II.Tr.E
	11:53	II.Sh.E
	21:19	I.Oc.D
June 9	0:51	I.Ec.R
	3:02	IV.Tr.I
	6:15	IV.Tr.E
	15:27	IV.Sh.I
	17:24	IV.Sh.E
	18:29	I.Tr.I
	19:44	I.Sh.I
	20:44	I.Tr.E
	21:58	I.Sh.E
June 10	0:49	II.Oc.D
	6:05	II.Ec.R
	14:28	III.Tr.I
	15:48	I.Oc.D
	17:48	III.Tr.E
	19:19	I.Ec.R
	19:39	III.Sh.I
	22:46	III.Sh.E
June 11	12:58	I.Tr.I
	14:13	I.Sh.I
	15:13	I.Tr.E
	16:26	I.Sh.E
	19:55	II.Tr.I
	22:29	II.Sh.I
	22:42	II.Tr.E
June 12	1:11	II.Sh.E
	10:17	I.Oc.D
	13:48	I.Ec.R
June 13	7:27	I.Tr.I
	8:41	I.Sh.I
	9:41	I.Tr.E
	10:55	I.Sh.E
	14:07	II.Oc.D
	19:23	II.Ec.R
June 14	4:35	III.Oc.D
	4:46	I.Oc.D
	7:58	III.Oc.R
	8:17	I.Ec.R
	9:48	III.Ec.D
	12:57	III.Ec.R
June 15	1:56	I.Tr.I
	3:10	I.Sh.I
	4:10	I.Tr.E
	5:24	I.Sh.E
	9:15	II.Tr.I
	11:47	II.Sh.I
	12:02	II.Tr.E
	14:29	II.Sh.E
	23:15	I.Oc.D
June 16	2:46	I.Ec.R
	20:25	I.Tr.I
	21:39	I.Sh.I
	22:40	I.Tr.E
	23:52	I.Sh.E
June 17	3:26	II.Oc.D
	8:40	II.Ec.R
	11:35	IV.Oc.D
	14:51	IV.Oc.R
	17:44	I.Oc.D
	18:32	III.Tr.I
	21:14	I.Ec.R
	21:51	III.Tr.E
	23:38	III.Sh.I
June 18	0:17	IV.Ec.D
	2:02	IV.Ec.R
	2:44	III.Sh.E
	14:54	I.Tr.I
	16:07	I.Sh.I
	17:09	I.Tr.E
	18:21	I.Sh.E
	22:34	II.Tr.I
June 19	1:05	II.Sh.I
	1:21	II.Tr.E
	3:47	II.Sh.E
	12:13	I.Oc.D
	15:43	I.Ec.R
June 20	9:23	I.Tr.I
	10:36	I.Sh.I
	11:38	I.Tr.E
	12:50	I.Sh.E
	16:46	II.Oc.D
	21:58	II.Ec.R
June 21	6:42	I.Oc.D
	8:41	III.Oc.D
	10:12	I.Ec.R
	12:04	III.Oc.R
	13:48	III.Ec.D
	16:56	III.Ec.R
June 22	3:52	I.Tr.I
	5:05	I.Sh.I
	6:07	I.Tr.E
	7:19	I.Sh.E
	11:55	II.Tr.I
	14:24	II.Sh.I
	14:41	II.Tr.E
	17:05	II.Sh.E
June 23	1:12	I.Oc.D
	4:41	I.Ec.R
	22:21	I.Tr.I
	23:34	I.Sh.I
June 24	0:36	I.Tr.E
	1:47	I.Sh.E
	6:05	II.Oc.D
	11:16	II.Ec.R
	19:41	I.Oc.D
	22:38	III.Tr.I
	23:09	I.Ec.R
June 25	1:58	III.Tr.E
	3:37	III.Sh.I
	6:42	III.Sh.E
	16:51	I.Tr.I
	18:02	I.Sh.I
	19:05	I.Tr.E
	20:16	I.Sh.E
	21:35	IV.Tr.I
June 26	0:47	IV.Tr.E
	1:15	II.Tr.I
	3:42	II.Sh.I
	4:02	II.Tr.E
	6:23	II.Sh.E
	9:34	IV.Sh.I
	11:14	IV.Sh.E
	14:10	I.Oc.D
	17:38	I.Ec.R
June 27	11:20	I.Tr.I
	12:31	I.Sh.I
	13:35	I.Tr.E
	14:45	I.Sh.E
	19:26	II.Oc.D
June 28	0:34	II.Ec.R
	8:40	I.Oc.D
	12:07	I.Ec.R
	12:51	III.Oc.D
	16:13	III.Oc.R
	17:48	III.Ec.D
	20:55	III.Ec.R
June 29	5:49	I.Tr.I
	7:00	I.Sh.I
	8:04	I.Tr.E
	9:14	I.Sh.E
	14:36	II.Tr.I
	17:00	II.Sh.I
	17:23	II.Tr.E
	19:41	II.Sh.E
June 30	3:09	I.Oc.D
	6:36	I.Ec.R

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

The ABCs of Lunar Craters

The alphabet plays a key role in identifying features on the Moon.

All lunar observers know Copernicus, Plato, Tycho, and probably a handful more of the 895 named craters on the nearside. But did you know that an additional 5,433 nearside craters have designations? These craters bear letters, not names. For example, a small dark halo crater southeast of Copernicus is called **Copernicus H**. And **Petavius B**, just north of its namesake, is a wonderful oblique impact crater with asymmetric rays.

Imagine the nightmare it would be for observers who wanted to learn their way around the Moon's surface if each of those 6,328 nearside craters had a distinct name honoring some historical figure. That's why letter designations exist for smaller or less prominent craters. When I wrote "Copernicus H" above, you probably knew immediately in what part of the Moon this feature is located — which would be a big help in finding it.

Many of the letter designations we use today derive from the famous *Mappa Selenographica*, published by German astronomers Wilhelm Beer and Johann Heinrich von Mädler from 1834 to 1836. Apparently Mädler did most of the observing and mapping, and Beer was a wealthy benefactor who supplied the telescope and observatory. Mädler systematically used capital letters as designations for craters of secondary interest. The aforementioned Petavius B appears on his map, for example.

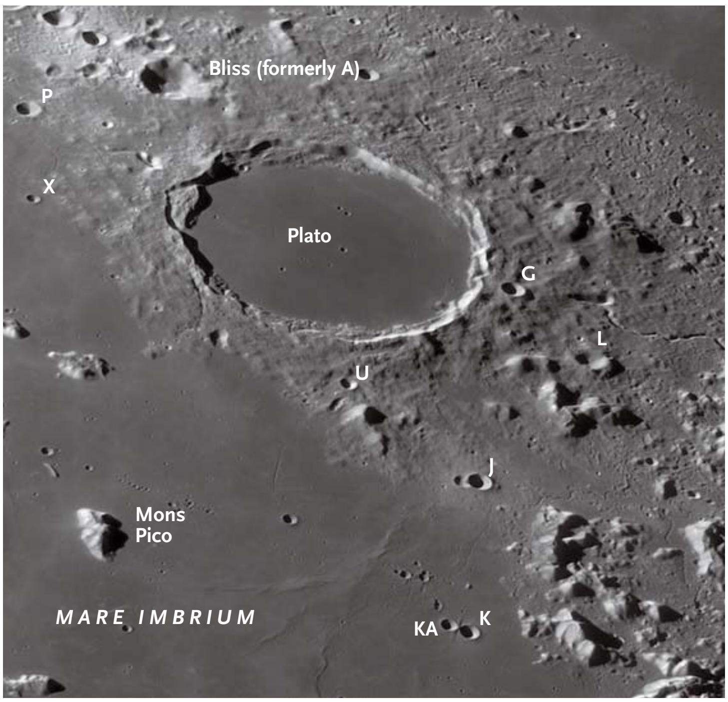
In general, Mädler gave the letter A to the most conspicuous crater positioned near the named primary feature. He reserved letters near the end of the alphabet for battered features, with the letter R often used for ghost rings, such as the beautiful but elusive Lambert R, and similar ruined craters.

On average, you'll find about six lettered craters for each named one on the Moon's nearside, but the counts vary greatly. Abulfeda is the crater with the most lettered features, 24, with only the letters I and V missing. Plato used to have 23 lettered craters, but in 2000 the surprisingly deep crater Plato A was renamed **Bliss**, after Rev. Nathaniel Bliss, who briefly served as Astronomer Royal in 18th-century England. (The story goes that Bliss was the only Astronomer Royal not honored with a crater name, so Patrick Moore lobbied for it.)

Two named craters have a double-lettered companion nearby: Abulfeda BA and Plato KA. Both cases involve two nearly same-size craters that touch. The Plato pair is intriguing because they formed simultaneously, and a curved ridge between them shows where ejecta from the two impacts collided. As with human twins, it seems reasonable that each of these lunar twins should have its own designation, thus **Plato K** and **Plato KA**.

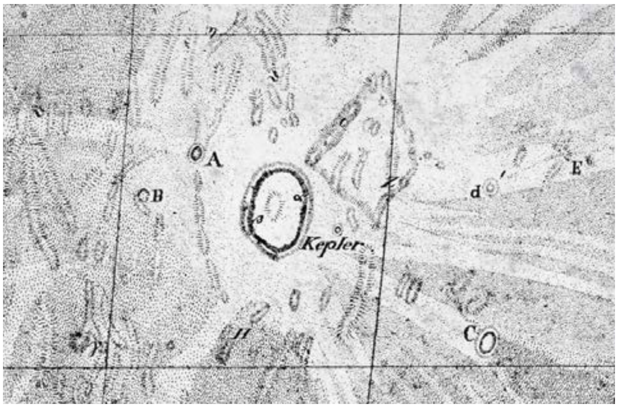
Many formerly lettered craters near the lunar limb acquired names in the 1960s and '70s, as Space Age images replaced the foreshortened telescopic perspectives available from Earth. The new overhead views provided by spacecraft showed so many differences that much improved mapping, and nomenclature, was needed. Newly named craters included Pascal, Krasnov, and Cannon, which were formerly designatedCarpenter D, Lagrange F, and Alhazen F, respectively. Few of you have probably knowingly seen these challenging features, but they're detectable with backyard telescopes when the libration is favorable.

Orbiting spacecraft also revealed thousands of previously unknown craters on the farside. Of these, 670 of the most prominent have been named by the International Astronomical Union, and in 1981 famed lunar

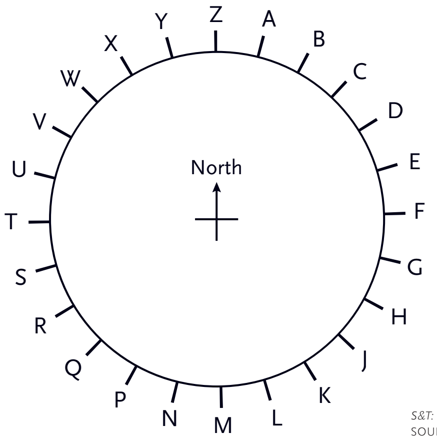


CHRISTIAN VILADRICH / LPOD

A dramatic image of 101-km-wide Plato also reveals several smaller lettered craters surrounding it — including enigmatic Plato K and Plato KA.



MAPPA SELENOGRAPHICA



S&T: LEAH TISCIONE; SOURCE: EWEN WHITAKER

Left: **Beer and Mädler's *Mappa Selenographica* (1834–36) used letters to identify small features near a large patronymic crater.**
Right: **Ewen Whitaker devised this lettering scheme for identifying small craters on the lunar farside.**

mapper Ewen Whitaker (University of Arizona) devised a clever system to assign letter designations for features near them. Whitaker imagined each named crater to be the center of a 24-hour clock, with 24 letters — omitting I and O — distributed around it. He assigned A to craters near the 1 o'clock position, M to those halfway around, and Z to 24 o'clock. Thus, unlike the somewhat haphazard situation on the lunar nearside, all farside letter designations follow a consistent scheme. Interestingly, the IAU earlier this year added two additional letter designations, Poincaré E and F, to farside craters now being mapped with Lunar Reconnaissance Orbiter data.

One of the most famous letter carriers is **Messier A**, the elliptical companion of **Messier** in Mare Fecunditatis. This dramatic duo probably formed when one grazing projectile created Messier then ricocheted down range to excavate Messier A. Another well-known lettered crater is Hesiodus A, the easiest concentric crater to detect telescopically.

For those lunar observers wanting a greater challenge, I encourage you to seek out Byrgius A and Marian T, and then to determine what's special about them. (Hint: Two online image maps — **http://is.gd/IAU_lunar_names** and **http://is.gd/LRO_lunar_names** — identify all named and lettered lunar craters. These show you where they are, but they don't explain what they are.)

The IAU classifies lettered craters as "satellite features," though typically they're not physically related to their patronymics. Instead, lettered craters most often are simply random impacts near a named crater. But some lettered craters *are* true secondary craters, excavated by ejecta thrown out by the formation of their named crater. For example, Copernicus B, E, F, G, and N are all secondary pits to the south of Copernicus itself. To its east are a dozen or so lettered craters that overlap and occur in lines. They're obviously secondaries from Copernicus as well — but because they are nearer to Stadius, they bear the name of that ruined crater.

Despite their utility, lettered craters are not used anywhere else in the solar system. Perhaps this is because in the early days of space exploration many members of the International Astronomical Union's Planetary Nomenclature Working Group had little experience with lunar maps, and the idea at the time was to honor fellow countrymen by placing their names on interplanetary bodies. Both Mars and Mercury bear thousands of impact-excavated craters — and, without the use of letters, vast numbers of names ultimately will be necessary to identify them. ✦

The Moon • June 2016

Phases

NEW MOON
June 5, 3:00 UT

FIRST QUARTER
June 12, 8:10 UT

FULL MOON
June 20, 11:02 UT

LAST QUARTER
June 27, 18:19 UT

NASA / LRO

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

Distances

Perigee 361,140 km	June 3, 11h UT diam. 33′ 5″
Apogee 405,024 km	June 15, 12h UT diam. 29′ 30″

Favorable Librations

Neper (crater)	June 8
Newton (crater)	June 18
Inghirami (crater)	June 21
Pythagoras (crater)	June 30

Thistledown

Grab hold of these galactic wisps in Virgo.

It is natural to assume that the elliptical nebulae are systems of many stars, whose great distance confines them to such a small area of the sky that their great multitude gives a pale, uniform glow, even though the light of each individual is imperceptible.

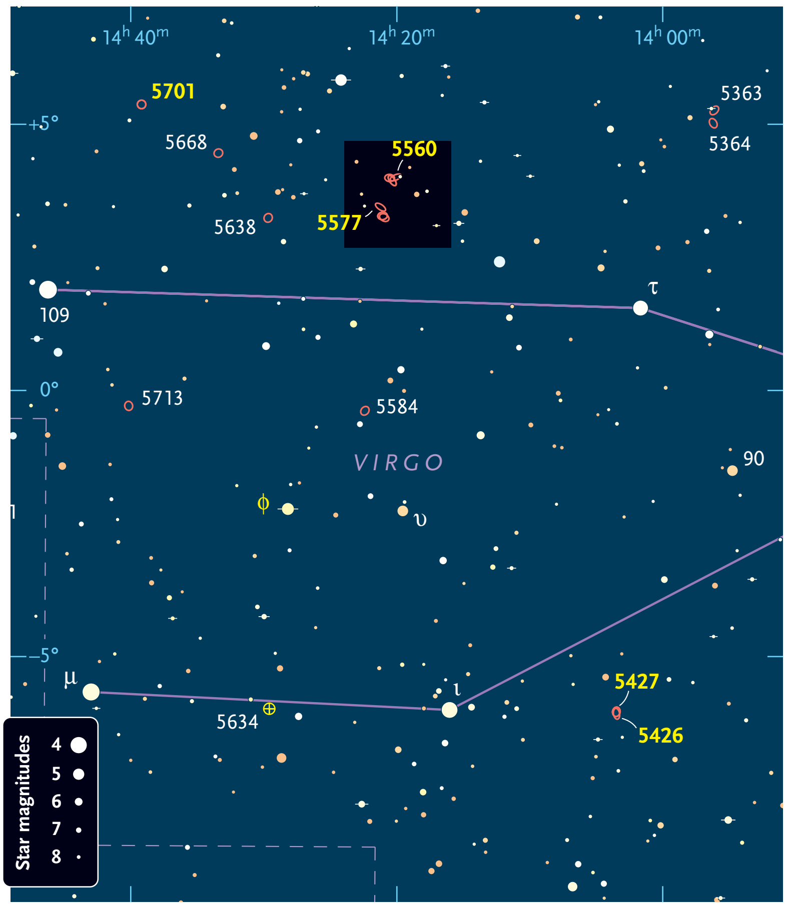
This now well-accepted claim isn't a statement from early last century, when the possibility of external galaxies became a hot topic in the scientific community. Rather, this is a paraphrase of an astonishing conclusion drawn by Immanuel Kant in his 1755 *Universal Natural History and Theory of the Heavens*. Kant was one of the earliest proponents of this concept, and what a mind-blowing idea it is!

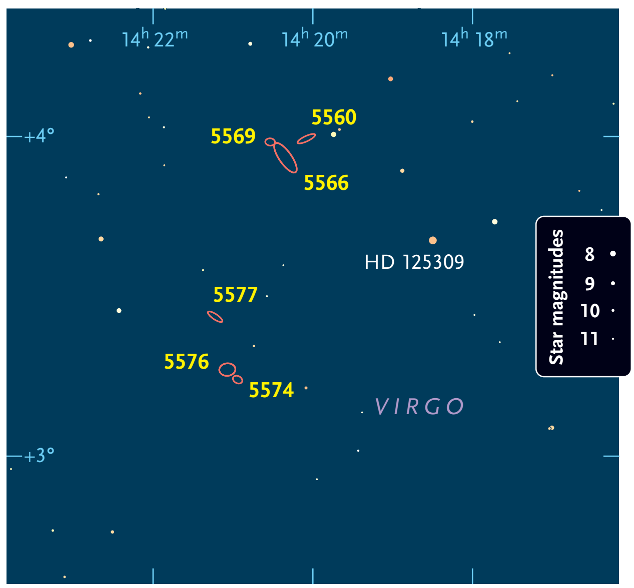
It's this knowledge that draws us out on starry nights to gaze at what Garrett Serviss called "small and inconspicuous wisps as ill-defined as bits of thistledown floating high in the air" (*Pleasures of the Telescope*, 1901). Today we have access to larger instruments than the 3-inch to 5-inch scopes addressed by Serviss, yet in any telescope there will be galaxies that resemble bits of thistledown — and we'll still go out to seek them.

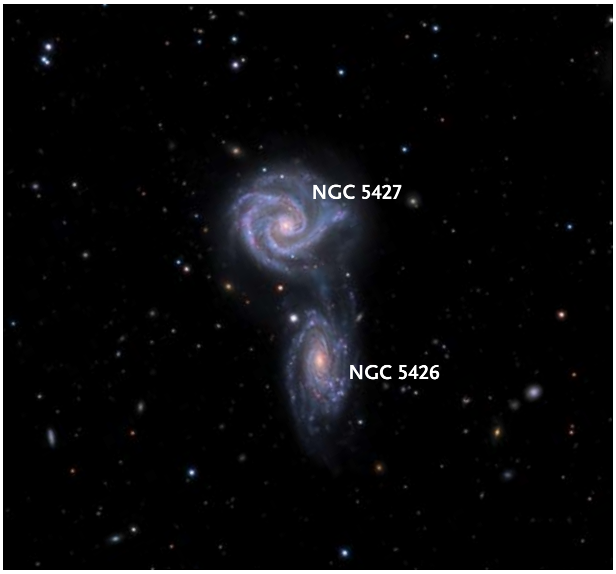
If you're hunting galaxies, Virgo is a great place to start. The constellation abounds with them, and it's not uncommon to see more than one Virgo galaxy in your telescope's field of view.

We'll begin with **NGC 5427** and **NGC 5426**, a pair of interacting spiral galaxies parked 3.1° due west of Iota (ι) Virginis. Through my 105-mm refractor at 47×, these are truly thistledown galaxies. NGC 5427 is easy to spot, though it only surrenders a small round glow and tiny bright nucleus to my eye, while NGC 5426 seems like a pale wisp reaching southward from its companion. Higher magnifications don't improve the view. The galaxies are chummy but don't appear to touch in my 10-inch reflector at 115×. NGC 5427 is a 2′ haze enveloping a starlike nucleus, and NGC 5426 is roughly 1½′ × 1′ with a faint star nuzzling the north-northeastern edge of its halo.

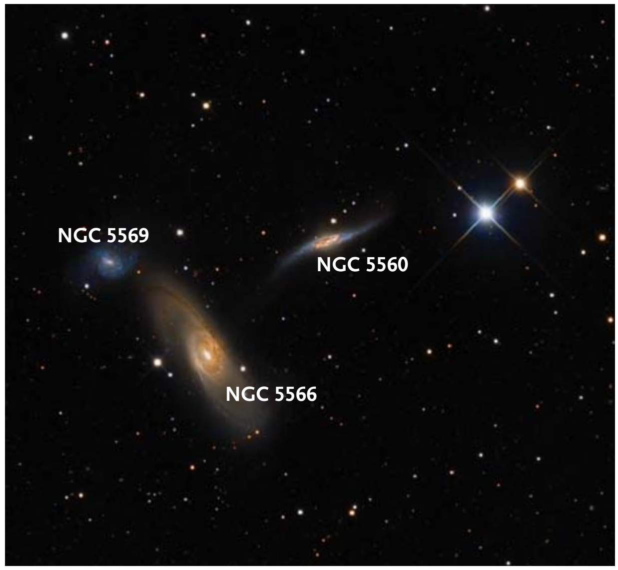
Why was I drawn to observe these bits of fluff? One look at a deep image pretty much answers that question. These beautiful spirals are embraced in a slow gravitational dance that will last many millions of years. They







ADAM BLOCK / MOUNT LEMMON SKYCENTER / UNIVERSITY OF ARIZONA



BOB FRANKE

Left: **Deep-sky images show a starry bridge forming between interacting spiral galaxies NGC 5426 and NGC 5427. *Right:* The elongation of NGC 5560 suggests that it belongs to an interacting galaxy trio including NGC 5566 and NGC 5569. This LRGB image, taken with a 12.5-inch f/9 Ritchey-Chrétien, highlights the dusty arms of NGC 5566 but also reveals the tight blue spiral of NGC 5569.**

may finish their waltz, wheeling past each other in their cosmic ballroom, or their mutual attraction might eventually pull them together, wedding these galaxies into one vast system. If that's not enough to stir your soul, ponder this: our Milky Way Galaxy and the Andromeda Galaxy may take up this same stately dance a few billion years from now. You could be previewing our future.

On the way to our next set of galaxies, let's pay a visit to **Phi (φ) Virginis**, a close double star with very unequal components, magnitudes 4.9 and 10.0. In my 105-mm scope they're separated at 122×, the faint attendant sitting east-southeast of its bright, golden primary. The dimmer star appears orange when viewed with my 10-inch scope at 166×. The primary star itself is suspected of being a very close binary. As stars go, this double or possibly triple system is relatively close to us at about 135 light-years.

Continuing our northward trek, we'll visit two galaxy triplets centered 5.2° east-northeast of Tau (τ) Virginis. Both groups can share a low-power field with the 7.0-magnitude star to their west, HD 125309.

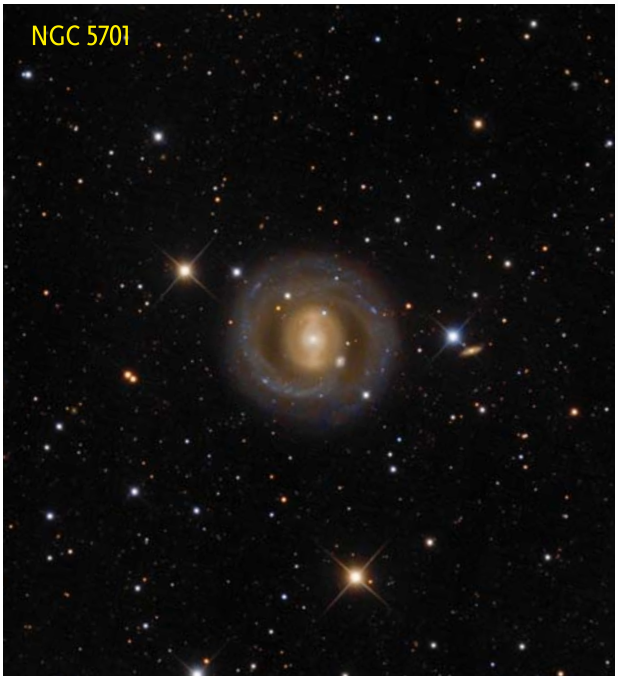
The southern triplet consists of **NGC 5576**, **NGC 5574**, and **NGC 5577**, in order of increasing difficulty. The first two can be spotted in the 105-mm refractor. At 28× NGC 5576 is a faint, very small oval that makes a 12.5′-tall right triangle with two 10th-magnitude stars, one northwest and the other west-southwest. At 87× the galaxy is considerably easier to see, showing off a brighter center within an east-west oval. At 122× it reveals a stellar nucleus. Sitting 2.8′ southwest, NGC 5574 is faintly visible with averted vision, and it's elongated almost parallel to the 10th-magnitude stars.

Through the 10-inch reflector at 115×, NGC 5576 has a faint, 2′ × 1′ halo surrounding a brighter, round core and a nearly stellar nucleus. A 13th-magnitude star rests 1.2′ northwest of the galaxy's center. NGC 5574 looks considerably smaller, a little more than 1′ long and perhaps 25″ wide, and it grows gently brighter toward the center.

Finding the Galactic Fluff

Object	Mag(v)	Size/Sep	RA	Dec.
NGC 5427	11.4	2.8′ × 2.4′	$14^h\ 03.4^m$	–6° 02′
NGC 5426	12.1	3.0′ × 1.6′	$14^h\ 03.4^m$	–6° 04′
φ Virginis	4.9, 10.0	5.3″	$14^h\ 28.2^m$	–2° 14′
NGC 5576	11.0	3.5′ × 2.2′	$14^h\ 21.1^m$	+3° 16′
NGC 5574	12.4	1.6′ × 1.0′	$14^h\ 20.9^m$	+3° 14′
NGC 5577	12.3	3.4′ × 1.0′	$14^h\ 21.2^m$	+3° 26′
NGC 5566	10.6	6.6′ × 2.2′	$14^h\ 20.3^m$	+3° 56′
NGC 5560	12.4	3.7′ × 0.7′	$14^h\ 20.1^m$	+4° 00′
NGC 5569	13.2	1.7′ × 1.4′	$14^h\ 20.5^m$	+3° 59′
NGC 5701	10.9	4.3′ × 4.1′	$14^h\ 39.2^m$	+5° 22′

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.



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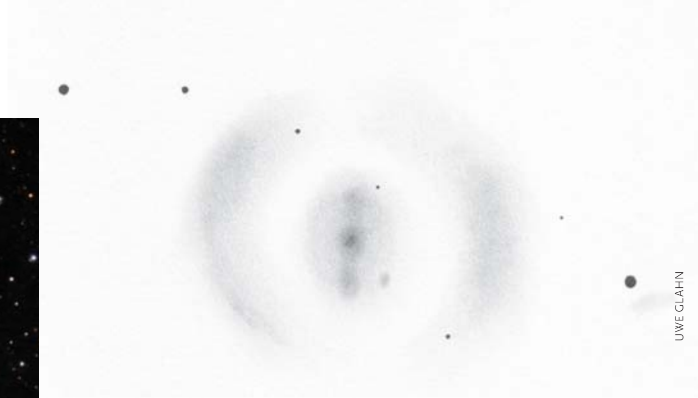


UWE GLAHN

Left: **In small-aperture scopes, NGC 5701 appears as an elongated fuzzy spot, but more magnification reveals the bright central bar at the galaxy's center. This LRGB exposure, taken with a 12.5-inch f/9 Ritchey-Chrétien, not only shows the bar, but also teases out the halo and arms. *Above:* Uwe Glahn captured the essential structure of NGC 5701 as viewed in a 27-inch f/4.2 Newtonian reflector.**

NGC 5577 is visible only with averted vision, its slender form running east-northeast to west-southwest. At 166× the galaxy looks approximately the same length as NGC 5576, and it holds a slightly brighter, elongated center.

This trio is about 80 million light-years distant. Studies show tidal tails in the vicinity of NGC 5576 and NGC 5574 that indicate a likely interaction between the couple. Tidal tails are streams of gas and stars pulled from galaxies in the same fashion that our Moon raises high tides on both the near and far sides of the Earth.

The northern triplet is an even tighter assemblage composed of **NGC 5566**, **NGC 5560**, and **NGC 5569**, all visible in my 105-mm scope. At 28× NGC 5566 displays a soft glow tipped north-northeast with a brighter center. At 87× a 12th-magnitude star closely inspects the galaxy's eastern flank, while a fainter star to the north watches the galaxy's opposite side from a more respectful distance. NGC 5560 reluctantly emerges as a gossamer smudge that requires averted vision. Upping the magnification to 122×, NGC 5566 sports a distinct, oval core that tilts northeast and a tiny, bright nucleus. NGC 5560's elongated form is significantly easier to spy, pointing west-northwest toward two bright stars, magnitudes 8.2 and 9.7. NGC 5569 manifests as a ghostly, round splotch off NGC 5566's north-northeastern tip.

Of course, all three galaxies are brighter and their features easier to discern through my 10-inch scope at 115×, but there's little to add. NGC 5566's halo covers about 4′ × 1′, its core is 1′ long, and the nucleus is starlike. The bright stars off NGC 5560's tip gleam yellow and orange, and a dim star accompanies the galaxy, north-northwest of center near its flank.

The northern trio is a bit farther away from us at a distance of roughly 90 million light-years. These galaxies are thought to form an interacting system, especially evident in NGC 5560, which appears to be stretched by the gravitational forces at work.

Interacting groups have great appeal because they present us with snapshots of a dynamic process distorting, transmuting, and sometimes merging galaxies. This takes place on a time scale far too long for us to watch, but if we study enough of these systems, we can get an idea of the possibilities and wind time forward in our minds to dream of what might occur.

Let's finish our excursion with the lone galaxy **NGC 5701**, located 3.9° north-northwest of 109 Virginis. At 47× my 105-mm refractor shows a small, north-south fuzzy spot. At 87× the galaxy grows brighter toward the center and appears about 1¾′ long and half as wide. Through the 10-inch at 166×, the part seen through the little refractor is intriguingly cocooned in a large, dim halo, and the bright region becomes a north-south bar with a small brighter core and an elusive, starlike nucleus. A 14th-magnitude star sits just off the halo's southwestern side, indicating an apparent diameter of a little less than 4′. A slightly fainter star is superimposed on the halo, north-northeast of the galaxy's center.

As we gaze out through the depths of space, no galaxy is truly alone on the sky. Halfway between the nucleus of NGC 5701 and the star at its southwestern edge is a 16.4-magnitude, 0.3′ background galaxy with the unmemorable name 2MASX J14390847+0521126. Perhaps those of you with very large scopes would like to give it a try. It could be your bit of thistledown. ✦

Howard Banich

An Unexpected Bloom

Take a fresh look at M20, the Trifid Nebula.

A few years ago I was thrilled when my step-daughter Kara unexpectedly arrived with her mom to join me at the Oregon Star Party for a few days. Upon seeing the **Trifid Nebula** (M20) for the first time she said, "Howie, it looks just like a dogwood blossom." I'd always thought it resembled a four-leaf clover, and not knowing what a dogwood blossom looks like, her comparison came as a surprise to me.

It was also unexpected enough that I looked it up when I got home — and sure enough, she was exactly right. Really, check it out.

Cloud-Cloud Collision

How the Trifid Nebula formed is even more unexpected. Nearly all H II regions start as molecular clouds (interstellar dust and hydrogen gas) collapsing under their own gravity with the help of an outside shove like a galactic density wave or a nearby supernova.

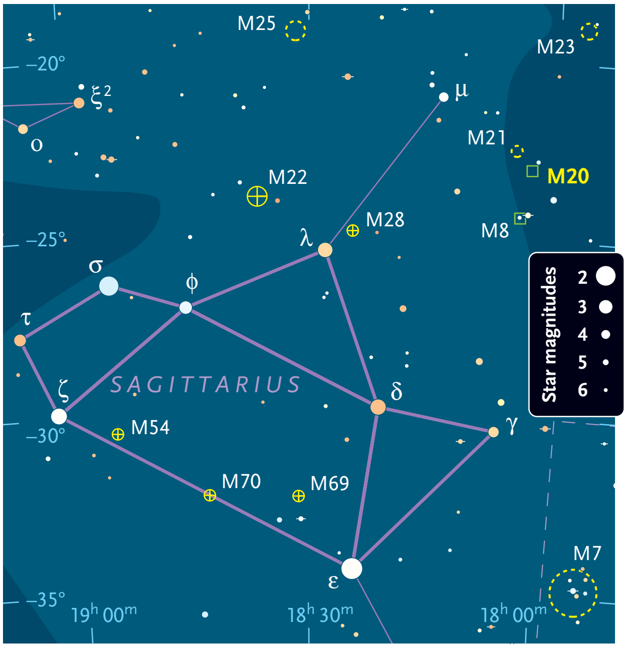
Not the Trifid. It's the result of two molecular clouds plowing into each other. That makes it an astrophysical rarity — it's only the second cloud-cloud collision H II region astronomres have ever discovered. Although cloud collisions are uncommon, the crowded and turbulent area around the Trifid Nebula is just the sort of place these pileups would happen.

The H II Region

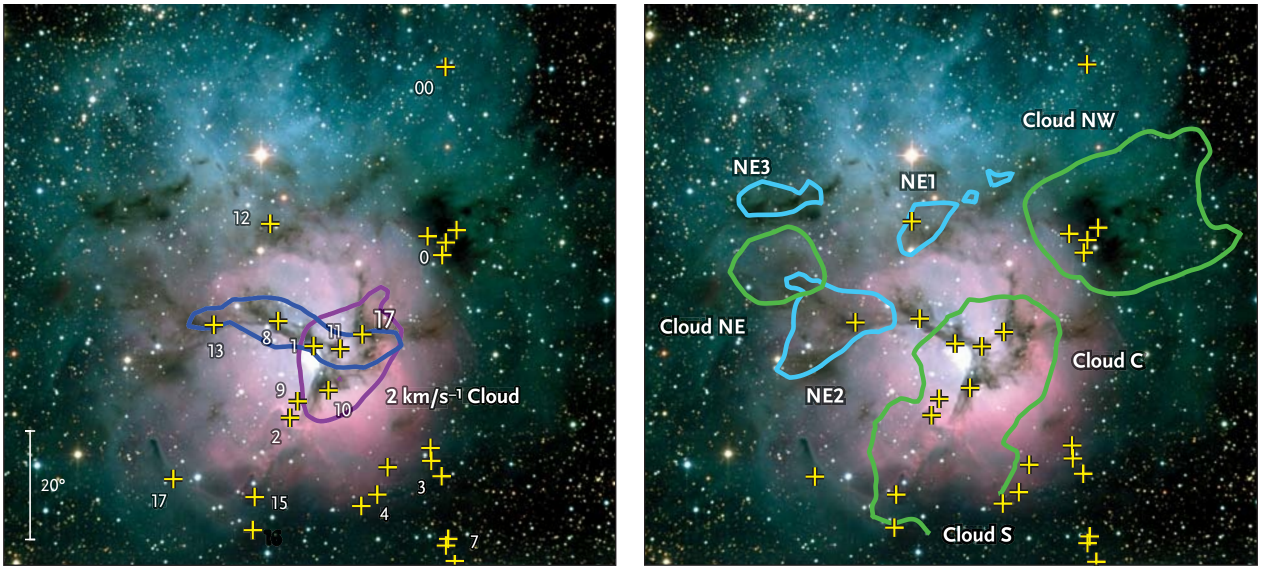
The two clouds, called the *2 km s^{-1} Cloud* and *Cloud C*, started colliding less than 1 million years ago and immediately began forming first-generation stars, including the monster HD 164492A. This is the powerful O7.5 star that doubly ionizes the Trifid's hydrogen gas with its intense ultraviolent output, creating the red H II region.

My most satisfying views have always been without filters on a great night, even though UHC and O III filters significantly boost contrast. The unfiltered, low-power view always shows more stars and is sometimes enhanced by the suggestion of color.

Created in a rare cloud-cloud collision, the Trifid Nebula is a young star-forming region about 5,200 light-years away in a turbulent section of the Scutum-Centaurus Arm of the Milky Way. Four major dark lanes front the continuous H II region, which is between 10 and 16 light-years in diameter. North is to the top of the image.



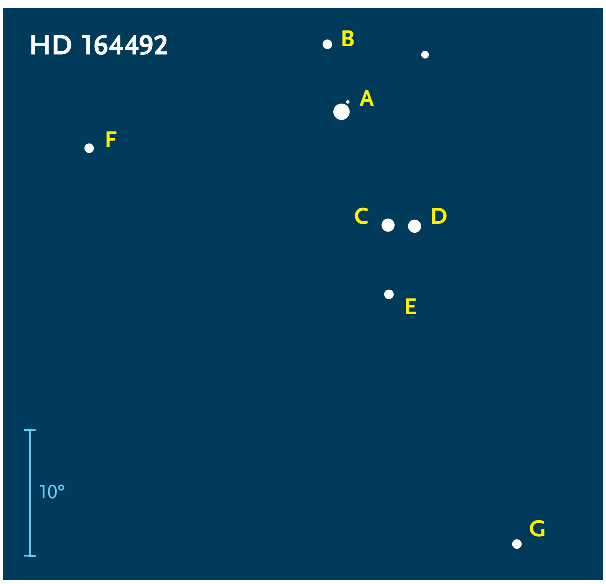
ERIC MARLATT / JON RISTA



The components of the *2 km s*[-1] *Cloud* are superimposed on a photo of the Trifid on the left. Small crosses mark the locations of dark cores and young stellar objects (YSOs); the numbers are their TC designations. The major molecular clouds are shown on the right. Taken from Torii et al (2011); links to this and other research articles about the Trifid Nebula can be found at http://is.gd/Trifid.

On an exceptionally transparent night, the H II region can take on a warm hue that subtly contrasts with the cool hue of the fainter reflection nebula to its north. It's delicate and may be an illusion, but it's still delightful to see.

The brightest H II areas are around the O7.5 star and just across the dark *Southern Lane* (SL). The southwestern H II region has a softly serrated inner edge along the central area between the SL and *Western Lane* (WL), and its outer perimeter gently fades to a nearly imperceptible edge. It's difficult to trace, even with averted vision. Almost the entire outer edge of the H II region is like this, except where it's bounded by the dark nebula, *Cloud NW*.



Components A through G (defined by Kohoutek, Mayer, and Lorenz, 1999) are best seen under a steady sky. The unmarked star northwest of A is as easy to see as B.

The two northern H II regions curl around each other and border the reflection nebula. The mostly straight and narrow *Northern Lane* (NL) separates them.

The buttery-smooth transition from the bright central H II area to the nearly imperceptible perimeter is a remarkable sight that's matched by few other nebulae.

Multiple Star HD 164492

HD 164492A is the brightest star near the intersection of the Trifid's dark lanes. It's not the only star visible here; even so, only its ultraviolet output is powerful enough to make the nebula glow as an H II region.

But that doesn't make the other stars uninteresting. They're part of the multiple star system dominated by HD 164492A and are first-generation stars created by the Trifid's colliding clouds. They're only about 300,000 years old. On a steady night, they can be seen aligned north-south and together form the bright heart of the Trifid. Stars A and C are the brightest and are easy to see at low power, while the fainter stars need more magnification. On a steady night I've seen components A through G with my 28-inch f/4 Newtonian using 408×.

Molecular Clouds and Dark Lanes

"Trifid" is a misnomer in large scopes. There are four main dark lanes — cataloged as Barnard 85 and more recently as the 2 km s^{-1} Cloud — that seemingly slice the H II region into four sections. When John Herschel described the nebula as "very large, trifid, three nebulae with a vacuity in the midst," he probably didn't see the Northern Lane.

Actually, the famous dark lanes are in front of the continuous H II area and are threaded with magnetic fields that support their shapes against their own gravity. They're also studded with young stellar objects (YSOs).

Possibly the most interesting Trifid YSO is inside the dark core nebula *TC2*, which is producing the jet HH 399. Material within the jet moves at approximately 400 km/s away from its deeply buried YSO.

The TC2 dark nebula can be seen near the end of the Southern Lane, appearing as a small, indefinite dark smudge. Contrast with its surroundings is quite low, so it's usually a challenging observation. HH 399's jet is probably unobservable with amateur telescopes, but at least it's not hidden from sight.

At the intersection of Barnard 85, just to the west of HD 164492, are three extremely thin dark filaments that can only be seen under the best observing conditions. Perhaps not coincidentally, they're radial to the *O*7.5 star. My best views have been at 253×.

Dark Cores

Most of the molecular clouds in and around the Trifid have dark cores in various stages of contraction. None of their YSOs can be seen in visible light, but some of their cocoons are visible as dark nebulae.

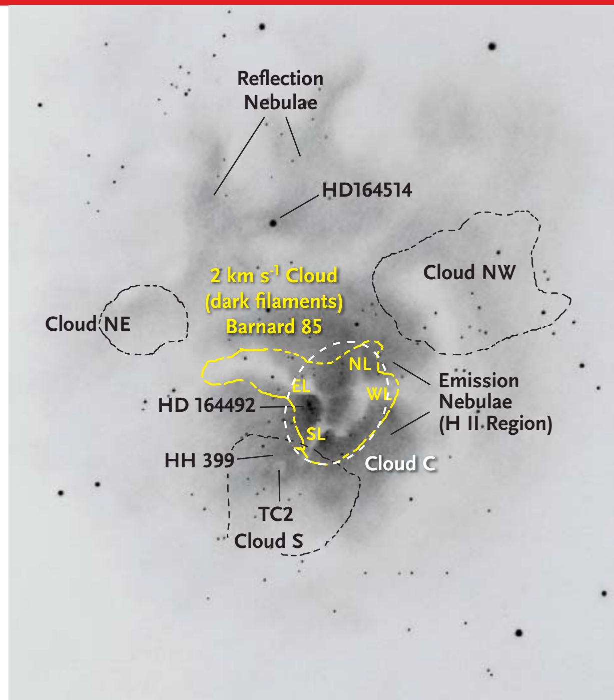
The dark area along the northwest edge of the H II region is, appropriately enough, referred to as *Cloud NW*. Visually, it's the largest dark nebula associated with the Trifid that's not a filament. It's most visible when the reflection nebula that faintly wraps around it is seen. One of its dark cores is *TC0* (zero).

Reflection Nebula

On the northern side of the Trifid is an intricate reflection nebula. The *A*7 star HD 164514 is its main source of illumination but isn't powerful enough to doubly ionize hydrogen gas. Dust grains mixed with the gas preferentially scatter blue light from HD 164514, creating the beautiful color contrast with the H II region seen in photos.

The two brightest areas of the reflection nebula form two soft arcs aligned north-south, and fainter swirls surround the entire H II region. There are also several dark nebulae that roughly trace the border between the H II and reflection nebulosity.

A dark and transparent sky is essential to see the reflection nebulosity well, and a broadband nebula filter may slightly improve contrast.



The Trifid is a busy place. This drawing was made over many nights spanning several years using my 28-inch f/4 Newtonian at magnifications from 135x to 408x. No filters were used. A total of 8.5 hours went into sketching at the eyepiece, with an additional several hours leading to this finished drawing. The 2km s^{-1} Cloud (Barnard 85), in the foreground, is moving toward us, while Cloud C, in the background, is moving away from us. Their positions were reversed at the beginning of their collision 1 million years ago. The labels refer to features discussed in the text.

A Special View

Observing the Trifid while the Milky Way stretches up from the southern horizon is often the best part of my summer observing. It's marvelous to trace the edges of the H II region along its northern border and see how the dark nebulae work with the dark lanes to define the Trifid's sumptuous shape. Seeing TC2 means the sky is really transparent.

Using a range of magnifications I'll count how many stars I can see in HD 164492, and then I'll back off the power to trace the extent of the dark lanes again. I'll use 135× to 408× depending on the night. It's endlessly fascinating.

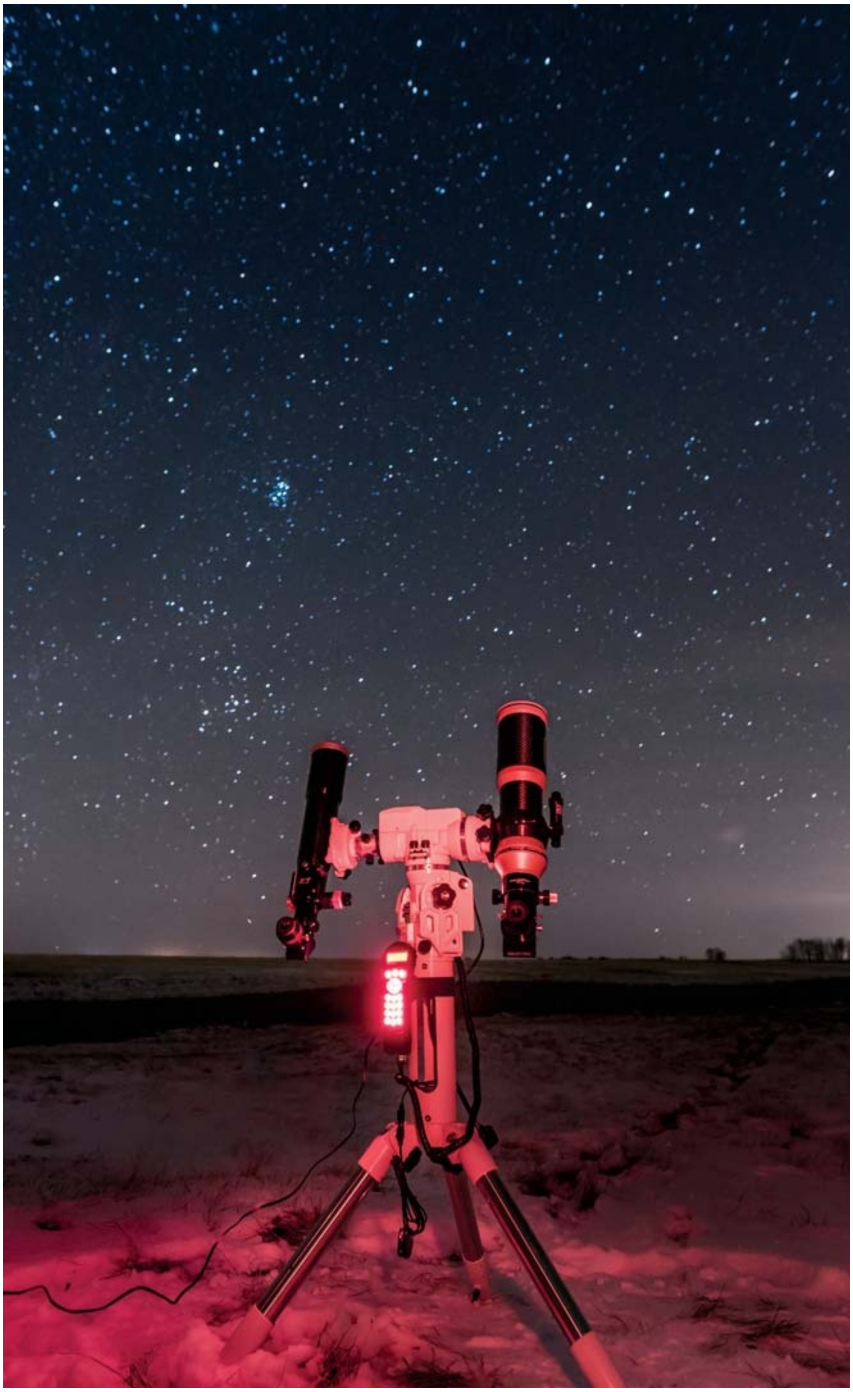
Then I'll just stare and appreciate the splendor. When one eye gets tired, I'll switch to the other. And then back again — it's too beautiful to easily turn away. An hour can happily slip by as the Trifid Nebula floats in my eyepiece, an unexpected dogwood blossom suspended in a field of stars. ✦

*If Contributing Editor **Howard Banich** had to choose, the Trifid Nebula would be his favorite deep-sky object. He can be reached at **howard.banich@nike.com**.*

Alan Dyer

Sky-Watcher's Dual-Purpose Mount

This mount offers versatility for both astrophotography and observing.



ALL PHOTOS BY THE AUTHOR

The new Sky-Watcher AZ-EQ5 Mount can be used in an alt-azimuth Go To configuration with dual telescopes, as seen here with it tracking under the stars, or as a traditional equatorial mount.

Sky-Watcher AZ-EQ5 Mount

U.S. price: $1,350

Available from skywatcherusa.com and dealers worldwide.

I CAN REMEMBER a time not long ago when aspiring astrophotographers had little to choose from in an entry-level telescope mount. Affordable mounts often had poor tracking and stability, while those that had good capabilities often cost well over $2,500. Now, those wanting to get into astrophotography without spending a bundle have a wide range of capable mounts to choose from.

One of the latest choices comes from Sky-Watcher in its AZ-EQ5 Mount. As its name implies, this portable mount can be used as either an alt-azimuth, for visual-only use, or as a German equatorial mount suitable for long-exposure imaging.

I tested the AZ-EQ5 in both modes and found it provided excellent tracking and Go To pointing accuracy in a light and portable mount great for impromptu use or serious photography, all for an affordable price.

Load Bearing?

The AZ-EQ5 is a small, lightweight mount. The mount head weighs just 16 pounds (7.3 kg), and 28 pounds complete with its matching half pier and tripod. The mount's modest weight makes for a convenient package to carry outside assembled as a unit. When collapsed to their shortest length, the tripod legs easily fit through doors and other entrances.

WHAT WE LIKE:

Equatorial and alt-az operation

Accurate Go To and tracking

Encoders allow manual movement

WHAT WE DON'T LIKE:

Optional outboard polar scope

High power draw

However, with the legs retracted the mount is quite short, with the saddle 41 inches (104 cm) above the ground. That may not be high enough for many refractors. Fully extending the legs raises the saddle another 8 inches.

One of the first things a potential buyer of any mount wants to know is "how big a telescope can it handle?" When used as an equatorial mount, the AZ-EQ5's advertised load capacity is 33 pounds, not including counterweights (two 7.5-pound weights are supplied). I tested it with the 8-inch Quattro Imaging Newtonian tube assembly (reviewed in the March issue) weighing 21 pounds, which required both counterweights. The mount proved to be too shaky for photography with this scope even with the axes locked down tight. However, weight isn't the only issue at play here; the length of the telescope tube, as well as how far that weight is from the rotational axes of the mount, is an important factor, especially with large Newtonian reflectors. An 8-inch Schmidt-Cassegrain would certainly perform better.

While the mount is sometimes depicted carrying 8-inch or larger reflectors, from my experience I'd suggest that if that's your intended load, consider Sky-Watcher's larger EQ6 mount.

But when mated to compact 3- to 4-inch refractors, the combination proved ideal, in either the equatorial mode with a single counterweight, or in the alt-azimuth mode with a pair of small telescopes. In either case, damping time was about one second with the legs fully retracted, making for a rock-steady platform.

Go To Pointing

The AZ-EQ5 is a Go To mount employing Sky-Watcher's SynScan system and its new Version 4 hand-controller. I've used the SynScan system on several Sky-Watcher mounts in recent years and have always found it reliable and easy to use. The new hand controller adds multi-language support.

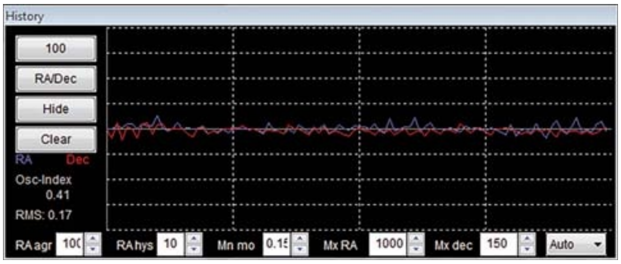
The only glitch I came across was a rare "runaway" where the mount continued to slew as if a button was still pressed. Hitting a slew button again stopped this, and fortunately the glitch did not affect the mount's knowledge of where it was pointed.

Indeed, a feature unique to the AZ-EQ5 and its bigger sibling, the AZ-EQ6, is what Sky-Watcher calls "Freedom Find." This employs dual encoders on the mount that keep track of the mount's position no matter how it is moved. You can unlock the mount and manually push it

The AZ-EQ5 comes with excellent azimuth and latitude adjustments for precise polar alignment. The latitude adjustment range spans from 0° to 90°. The ribbed black wheel (seen on the counterweight shaft) is the declination lock. Note the secure locking plugs for the declination and power cables, a professional touch.

The large ratcheted handle (right) makes quick work when adjusting the latitude angle. The control panel contains ports for the hand controller, a standard ST-4 autoguider, and a USB jack for computer control. Two "SNAP" ports allow users to connect their DSLR cameras and control their shutters with the SynScan hand paddle. The ribbed black wheel seen here is the RA lock. The saddle accepts Vixen-standard dovetail plates.

An outboard polar alignment scope bolts securely to the mount, replacing a small bubble level used in alt-azimuth mode. The separate "bright field" illuminator is shown on the front of the polar scope.



The author tested the mount's guiding using a TMB 92-mm f/5.4 refractor as the imaging telescope and a 50-mm guidescope with an Orion StarShoot autoguider. As the guiding graph from *PHD Guiding* shows, the AZ-EQ5 guided very smoothly, with no abrupt runaways or oscillations.

around the sky and it still retains knowledge of where it is pointed. If you are using the mount in a public viewing session and someone accidentally grabs and moves the telescope, even with the axes locked, no problem. Just re-select the object you were aimed at and press Enter, and the mount returns to your target. Very nice!

I found this feature worked great in either equatorial or alt-azimuth mode, faithfully centering targets even after purposely bumping the scope far off target.

Aligning the Go To system proved fast and reliable, never yielding a dreaded "Alignment Failed" message. Our test unit, supplied on loan from Pacific Telescopes in Canada, came with the separate SynScan GPS module (optional in most other markets) that automatically feeds the current location and time to the hand controller. This sometimes took a couple of minutes to acquire a fix, but it always succeeded. With it, one still needs to step through menu pages to confirm your time zone and Daylight Time status.

When set to 90° latitude and locked, the AZ-EQ5 becomes an alt-azimuth Go To mount, for use with one telescope and the supplied counterweights.

In equatorial mode, from the standard starting position with the mount roughly level, polar aligned, and aimed north, you have a choice of 1-, 2-, or 3-star alignments. For the best accuracy in testing, I used 3-star alignments, in which the mount picks two stars on the west side of the meridian and a third star in the east. The mount slewed to the first star but was usually a few degrees off, typical of most Go To systems. The mount then aimed much closer to the next two alignment stars, often placing them near the center of the eyepiece.

In alt-azimuth mode, you can have it automatically choose the "Brightest Star" in a selected region of sky, an option for those who can't identify any stars. Or you can use a 2-star alignment, in which you select the stars and manually slew to the first star.

Once aligned in either mode, the AZ-EQ5 accurately slewed to every object I chose no matter where it was in the sky, usually placing it dead center or, as was the case with the occasional target, in the central 50% of a low-power eyepiece. This is a Go To system that just works.

Cord wrap wasn't a problem either. For one thing, the only cable that runs from a moving to a fixed part of the mount is the one for the declination motor, and not the all-important power cord. So unlike some Go To mounts, there is no concern about the power cord being yanked out unexpectedly as the mount slews around.

Even so, the hand controller's intelligence nicely prevented the mount from always going in one direction, forcing the mount to backtrack and go the "long way around" when slewing from object to object on either side of the meridian near the pole. This prevented any cord wrap problems.

The "Park" function also worked fine in either mode. This can slew the mount back to a standard home position or simply leave it where it is, where it can be turned off then powered up later to resume Go To operation with no re-alignment needed.

Polar Alignment

While in equatorial mode, the mount requires at least a rough polar alignment for the Go To system to function. But for long-exposure imaging and tracking, polar alignment has to be accurate. However, the design of the AZ-EQ5 precludes any polar alignment scope mounted within the polar axis itself.

Instead, the mount uses an optional polar scope that attaches to the side of the mount with a solid bracket. When packing the mount head away, the polar scope needs to be removed and stored separately, then re-attached each time. That's an inconvenience, though it's simple enough to assemble using the captive bolts.

Initially I was concerned that the repeated assembly of the polar scope would upset its alignment with the polar axis. This proved to be a non-issue. Despite some play in the bolt holes, it was easy to replace the polar scope consistently each time to achieve accurate polar alignment and excellent photographic tracking.

More of an inconvenience is that its "bright-field" illuminator is a separate battery-powered unit you place over the front of the polar scope. It works fine, but is an item that could easily be forgotten or misplaced.

Tracking Accuracy

By visually inspecting a guide star on a cross-hair eyepiece, I checked for the smoothness of the tracking. The motors employ belt drives, so the mount didn't exhibit the traditional back-and-forth periodic error of a worm gear drive. The guide star stayed nearly motionless within the reticle's 10-arcsecond box for at least 10 minutes. But then, over a couple of minutes, it would slowly drift off to a new position about 30 arcseconds away where it would sit for many more minutes.

An autoguider would handle this drift with no problem. Indeed, the mount guided beautifully using an Orion StarShoot autoguider and *PHD Guiding* software. However, this performance was with a small 50-mm guidescope and a 92-mm refractor as the imaging optic. Weigh the mount down with too much load, and tracking accuracy will certainly suffer, especially on windy nights. Using my modest load, I was able to consistently get well-guided images with exposures of 5 to 10 minutes.

Alt-Azimuth Mode

Of course, you could use the AZ-EQ5 as an equatorial mount full-time, even if you had no desire to take pictures. However, the advantage of its alt-azimuth mode is that polar alignment is not required to find and track objects. So that's one less step to worry about in setup — handy for grab-and-go observing.

The other advantage of alt-azimuth mode is that the mount can then handle two telescopes, albeit of modest size, aimed at the same object. To this end, the mount comes with a second saddle unit that bolts onto the retractable counterweight shaft.

The AZ-EQ5 reliably guided many 10-minute exposures, including this image of IC 1848, the Soul Nebula, with a TMB92 Signature Series f/5.5 apochromatic refractor. Total exposure was 50 minutes with a modified Canon EOS 5D MkII DSLR camera.

A dual-scope setup can be particularly useful for solar observing, allowing for simultaneous white-light and Hα scopes, or at night for comparing wide-field and high-power views, or for star parties and public outreach.

The second saddle comes with fine adjustments to align the second telescope to the main telescope in altitude, but not in azimuth. However, I found the second scope aligned almost perfectly with the main scope the first time I assembled my two-scope test rig, with little need for fine-tuning. The result was a combination that was fun to use and scan around the sky manually, knowing the "Freedom Find" encoders would track the mount's position and still allow a Go To slew when needed.

The switch from equatorial to alt-azimuth mode is quick and easy. Simply turn the mount's latitude up to 90°, and then tighten a captive bolt to hold the head securely in position. In this mode, you still need to perform a two-star alignment, first by manually slewing the scope to a known star to begin the process.

Despite the motors now having to turn at varying rates in each axis, the mount followed objects just fine. Even targets such as the Andromeda Galaxy (M31) stayed well centered even over a couple of hours when passing overhead.

Additional Features

I did much of my testing on autumn and winter nights in temperatures well below freezing. The mount never had any problems in the cold or became hard to move, while the controller's LCD display remained surprisingly readable. Indeed, the mount slewed very quietly at all times, despite much of the head having plastic covers.

Using the included RS-232 cable I was able to control the mount from my iPad using the *SkySafari Pro* app. Both the wireless SkyFi and wired SkyWire worked fine with "Sky-Watcher SynScan" selected as the telescope of choice in the app.

The secondary saddle has two fine adjustment knobs for co-aligning the second telescope in altitude to match the field of the main telescope. No adjustment capability is provided for azimuth, though none was needed.

A second supplied dovetail saddle can be bolted to the counter-weight shaft to handle an additional smaller telescope. Like the main saddle, the second saddle accepts a Vixen dovetail plate.

The AZ-EQ5 comes with a power cord to plug into a 12-volt car lighter jack or into Sky-Watcher's optional AC-to-DC power supply. However, powering the mount from one of the popular and compact lithium batteries, with their standard 12-mm barrel connectors, will require an adapter cable to go from your battery's barrel plug to a female cigarette lighter jack, as the mount head uses a unique, though lockable, power jack, not the 12-mm barrel connector most other telescopes use.

I did find the mount rather power hungry, depleting a large jump-start battery in just a short evening of viewing. The specifications state the mount draws a hefty 3 amps at 11 volts. I would not run this mount off your car battery from a remote site! If the voltage drops below 11 volts the mount's power light begins to flash a warning, and if the voltage drops too low, the instructions advise that the mount or hand controller could be damaged. Even worse, your car might not start!

The mount has two "SNAP" ports that can control a DSLR camera shutter using the supplied cables suitable for Canon cameras that use Canon's E3-style mini-phono plug. Cables for other cameras are available from Sky-Watcher or from camera stores. The hand controller can be used to program and store up to eight exposure and interval combinations. This worked well, though the two ports supply the same commands to each camera.

In all, the AZ-EQ5 proved to be an excellent performer for anyone looking for a lightweight, affordable mount. At approximately $1,350, plus options, it's slightly more costly than other mounts in its weight class. But the versatility of the dual-mode operation, its accurate tracking, and the convenience of its "Freedom Find" encoders are all very appealing. I've added the AZ-EQ5 to my list of recommended entry-level mounts. ✦

Contributing editor Alan Dyer is author of the ebook How to Photograph & Process Nightscapes and Time-Lapses *available at* **amazingsky.com/nightscapesbook.html.**

▲ **MINI APO** Stellarvue introduces the SV70T apochromatic refractor ($799). This compact 70-mm f/6 triplet uses an Ohara FPL53 ED element combined with broadband coatings to achieve high-contrast views free from color fringing. Weighing just 5.6 pounds with a pair of hinged tube rings and a Vixen-style dovetail bar, the SV70T is a perfect grab-and-go telescope for casual observing. Its 2½-inch dual-speed, rack-and-pinion focuser includes both 2- and 1¼-inch eyepiece adapters, and accepts the optional SFFR-70APO focal reducer/field flattener ($295), converting the instrument into an f/4.8 wide-field astrograph. See the manufacturer's website for additional details.

Stellarvue
11820 Kemper Rd., Auburn, CA 95603
530-823-7796; stellarvue.com

▼ **VIDEO SUITE** There's a new tool for fans of video-assisted observing. The Revolution Imager ($299.99) is a complete video observing package that includes everything you'll need to broadcast the views from your telescope. This color CCD video camera automatically integrates exposures that are then displayed on the included 7-inch LCD monitor to produce near-real-time views of astronomical targets. The Revolution Imager kit comes with a 1¼-inch nosepiece adapter, a 0.5× focal reducer, a UV/IR blocking filter, hand-held remote controls, and a 12-volt rechargeable battery that powers both the camera and monitor.

Revolution Imager
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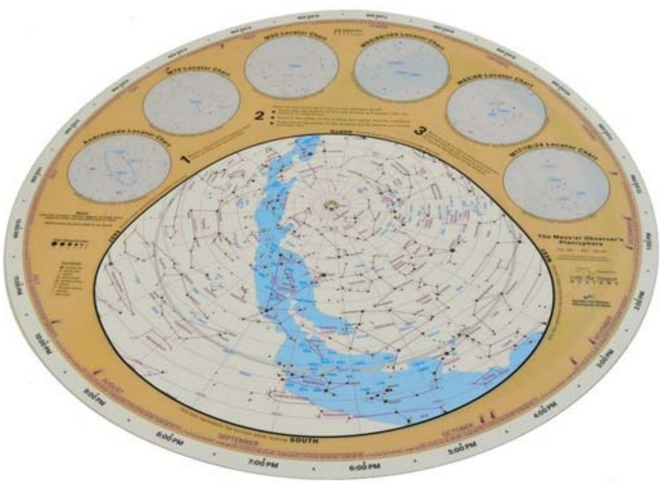

◀ **MESSIER PLANISPHERE** Celestial Teapot Designs brings you the Messier Observer's Planisphere ($29.99). This large, 18¼-inch-diameter planisphere is designed to make your next Messier Marathon easier by guiding you to all 110 targets (plus 25 bright NGC objects) with most any telescope or binoculars. Bright stars and constellations are labeled, and light shading denotes the area of the Milky Way. The reverse side features detailed maps of the Virgo Cluster of galaxies and two of the more challenging targets, as well as a reference table with additional information.

Celestial Teapot Designs
727 Reliance Dr., Buda, TX 78610
messierplanisphere.com

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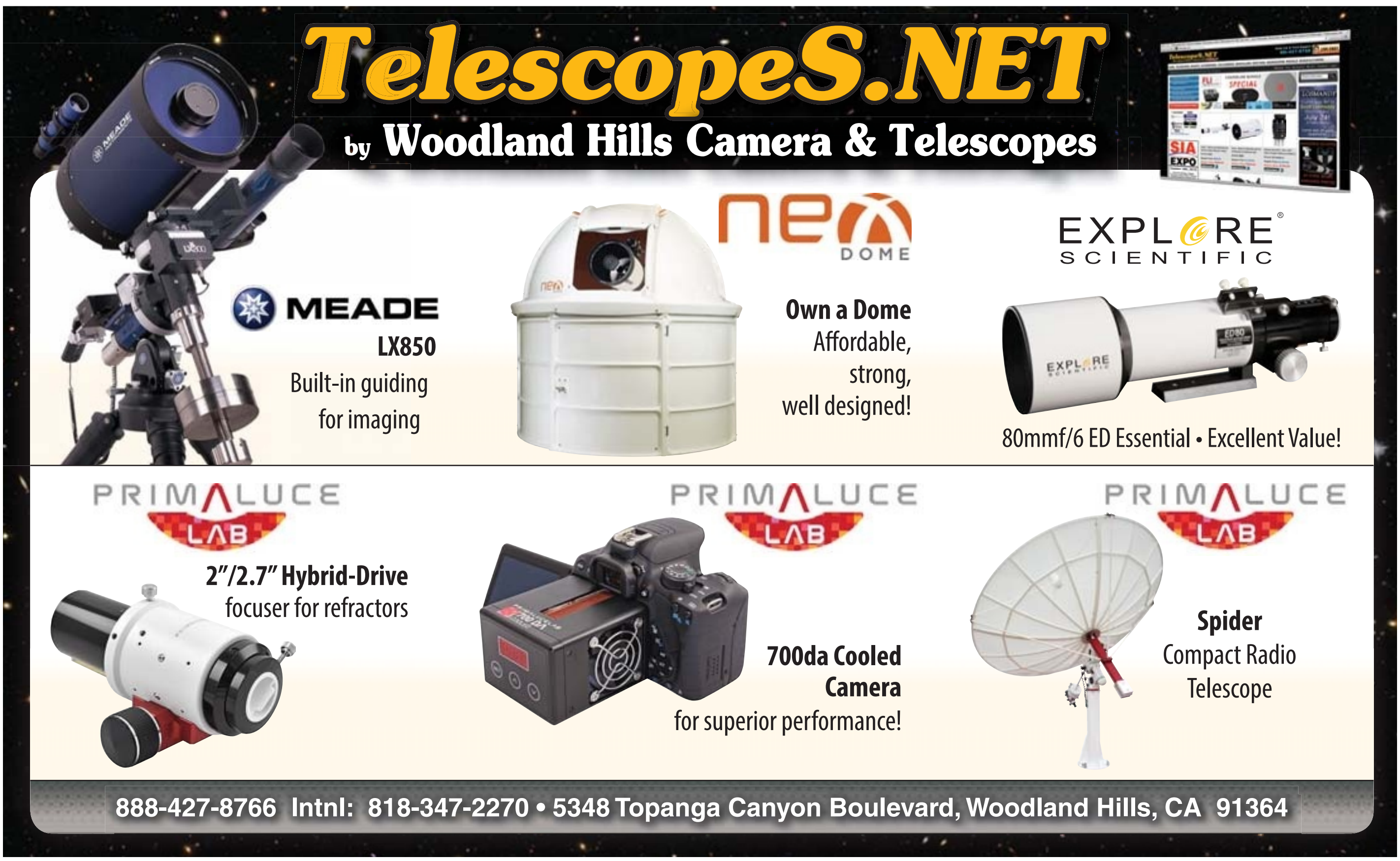

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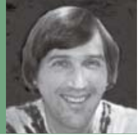


Why Do It Yourself?

The reasons go far beyond mere economics.

I LOVE TO BUILD THINGS. I also love to share what I've learned in the process. If you've followed Gary Seronik's Telescope Workshop column over the years, you've seen a half dozen of my projects, including my flex equatorial platform highlighted in the April issue. So when Gary told me he was becoming editor of *SkyNews*, and *Sky & Telescope* asked if I'd be interested in continuing his column, I jumped at the chance.

Gary left a mighty big pair of shoes to fill. I will never replace him; all I can do is continue the column in my own way and do my very best to keep it as interesting and informative and inspiring as he did. I don't plan to change much. Gary had a winning approach, and I'm not going to mess with it.

Author Jerry Oltion with some of his homemade telescopes.

KATHY OLTION

You'll notice one change immediately, however: the title at the top of the page. Telescope Workshop was Gary's column. We're calling mine Astronomer's Workbench, because that title encompasses what the old column did plus opens it up a little wider. I plan to feature not just innovative homebuilt telescopes but practically anything homebuilt having to do with astronomy. Amateur telescope makers build far more than just telescopes, and I want to cast a spotlight on all of it. Over time I hope to cover pretty much everything you'd want or need to build for practicing the coolest hobby ever.

Why do people build their own equipment, anyway? Lower cost used to be a compelling reason, but not so much anymore. Unless you're making a big scope, it probably costs just as much to grind a mirror and have it coated as it does to buy one already made. For that matter, you can buy an entire 8-inch Dobsonian for about the price of the parts needed to build it yourself.

Ah, but try to find one with an f/3 focal ratio, or with a collapsible mount, or made of inlaid oak. Try to find a red flashlight with just the right amount of glow for your sketching, or a focuser that weighs three ounces.

Even if you can find those things available commercially, there's still the pleasure of crafting them yourself, of working with your hands, of standing in the shop or the hardware store, staring off into space while your mind tries to fit the shape you need into the possibilities around you. You haven't lived as an ATM until you've realized that a 5-gallon bucket makes the perfect secondary cage for a 10-inch reflector.

Like so many things, it's about the process as well as the product. Making something yourself provides immense satisfaction. Whether your creation looks like an engineering masterpiece or a child's crayon drawing brought to life, when you put your eye to the eyepiece of a homemade scope and look at photons bouncing off a mirror you ground, there's a sense of accomplishment like no other.

Best of all, it's surprisingly easy to do! If I stress only one thing in the months to come, I want it to be this: making your own astronomy gear is easier than you think. If you understand the principles involved and have a little patience, you can build practically anything.

JERRY OLTION

ATMs make much more than just telescopes. Here are some upcoming projects we plan to cover, including homemade finders, collimators, red flashlights, a solar filter, and an observing chair.

You don't need much equipment to get started. You don't even need shop space. Gary ground his first few mirrors in an apartment closet and sawed the lumber in his kitchen.

In future columns, I'll show you how to make a variable-intensity red flashlight for practically nothing, as well as how to craft your own collimators (both Cheshire and laser), finders, eyepieces (yes, eyepieces — piece of cake!), an observing chair, and whatever else I can fit in the available space. Some will be my own creations, but I'm counting on you, *Sky & Telescope* readers, to submit your projects for consideration, too. I want to see your coolest work, from the simplest accessory to a complete telescope, and to share it with the world.

The workbench is ready. The lights are on. Let's have some fun. ✦

Contributing Editor ***Jerry Oltion*** *is an accomplished telescope maker and observer. He welcomes your project submissions. Contact him at* ***j.oltion@sff.net***.

S. N. Johnson-Roehr

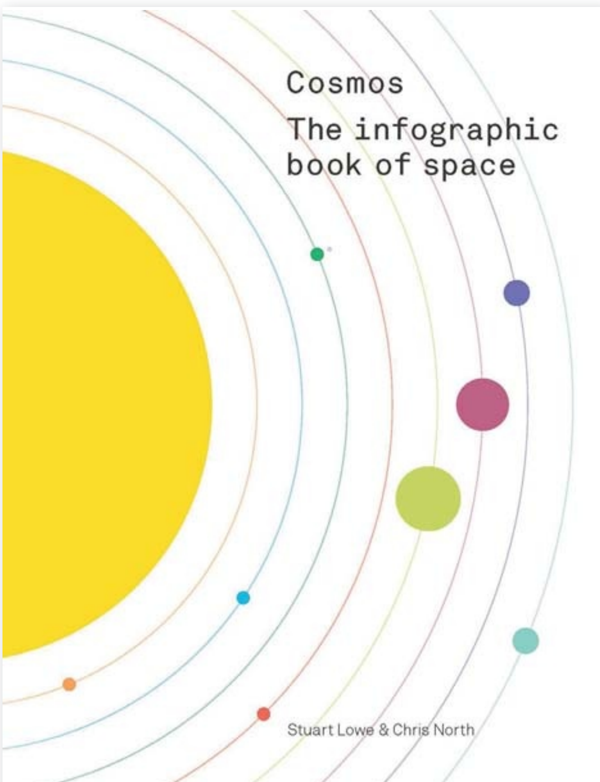
Representing the Universe

Cosmos: The Infographic Book of Space

Stuart Lowe & Chris North
Aurum Press, 2015
224 pages, ISBN 9781781314500, $34.99, hardcover.

PARTNERING TO WRITE a popular science book is common practice, with frequently good results. Yet it's only occasionally that those results are as visually delightful and intellectually stimulating as *Cosmos: The Infographic Book of Space*, co-authored by Stuart Lowe (formerly of Jodrell Bank Observatory) and Chris North (Cardiff University).

In addition to working as professional astrophysicists, Lowe and North take a keen interest in public outreach. North is a familiar figure with the BBC's astro audience; Lowe co-founded the madly popular Jodcast and has brought his considerable coding skills to bear on projects meant to give greater public access to astronomical data. In *Cosmos*, the two scientists have combined their knowledge and talents to produce an entertaining and informative read.



One of the challenges in astronomy education is explaining complex processes that occur at scales and distances almost beyond human comprehension. What does it mean to say that a galaxy is 20 orders of magnitude larger than a human being? How do you describe the relationship of two such disparate objects in a way that makes sense to a lay audience?

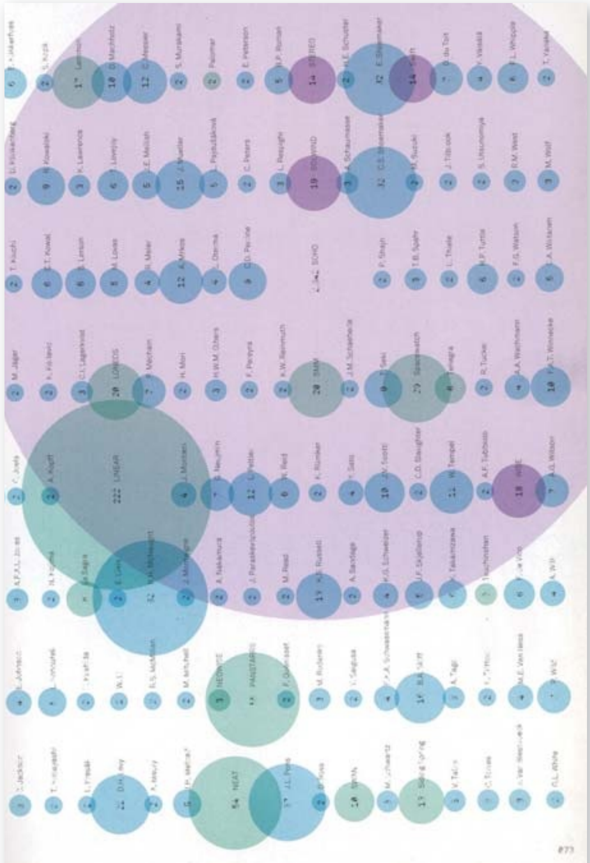
Cosmos is an experiment in solving these communication obstacles through infographics — full-spread depictions of data that rely heavily on the visual component. A good infographic represents not only data, but an analysis of that data. We're all familiar with flowcharts, timelines, and graphs; these are commonly used approaches to "crunching numbers" and visually explaining the outcome. Lowe and North go far beyond the ordinary office pie chart, though, using a variety of approaches to explain data analyses in various subfields of space science.

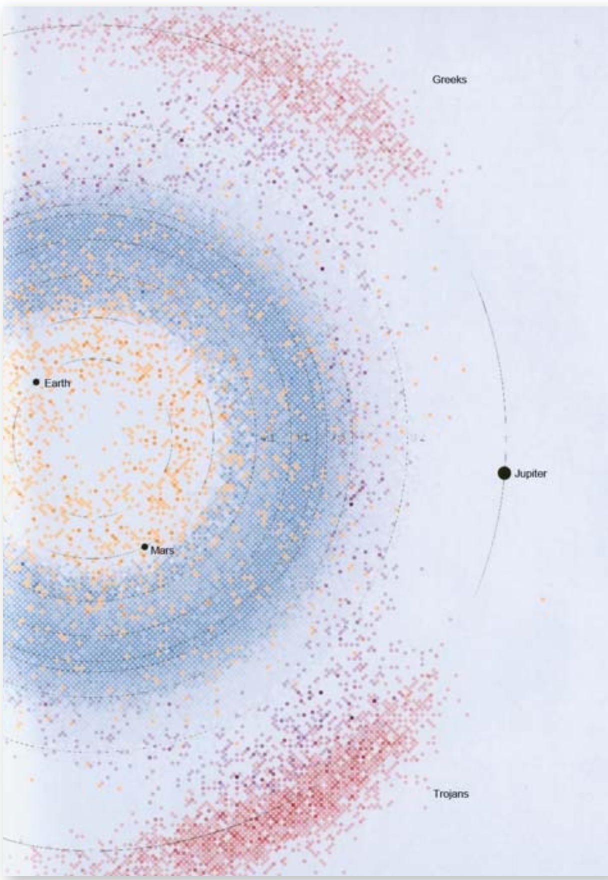
What Lowe and North prove is that infographics are well-suited for depicting relationships — spatial, scalar, or otherwise. Consider, for example, the diagram representing the history of comet discoveries. It's one thing to know that Wilhelm Tempel discovered 12 comets while the SOHO satellite has discovered 2,842. It's another thing to see those numbers represented by proportional circles. SOHO's circle could swallow Tempel's many times over, proving the era of visual comet hunters is all but over.

Infographics are also useful for revealing patterns. I literally said "Wow!" when I landed on the page showing the locations of asteroids. Could the distribution of Trojan asteroids at the Sun–Jupiter Lagrange points be made any more obvious? Similarly, a plot of pulsars' rotation rates (see p. 140 of the book) against their rate of slow-down makes clear the relationship between the two (a pulsar rotates more slowly as it ages and loses energy). But what's that outlier, J2144-3933, doing all by itself on the far side of the "pulsar death line"? Why doesn't it follow the pattern of other detected pulsars? Will we detect more on the "wrong" side of the line, and if so, how will they change our understanding of stellar death?

Lowe and North cover so many topics, everyone should find something of interest here. In addition to a short introduction, *Cosmos* includes nine chapters: Space Exploration; Solar System; Telescopes; The Sun; Stars; Galaxies; Cosmology; Other Worlds; and Miscellaneous. Each chapter is keyed to a single color. For instance, the pages in "Solar System" have a blue background, while those in "The Sun" are yellow. The steady palette makes it easy to jump from chapter to chapter, which is useful as the book lacks a detailed index.

As many space fans might guess from looking at their bookshelves, one difficulty in writing about science is that information rapidly goes out of date. Lowe and North took this into account, giving the book a long afterlife in the form of a frequently updated website (**cosmos-book.github.io**). The site includes a JavaScript repository that supports interactive versions of some of the infographics (spoiler alert: jumping on the Moon might be fun, but it's probably unnerving to jump on Enceladus, and a very, very bad idea to jump on Phobos). That site also has a list of sources and a commendably short list of errata.

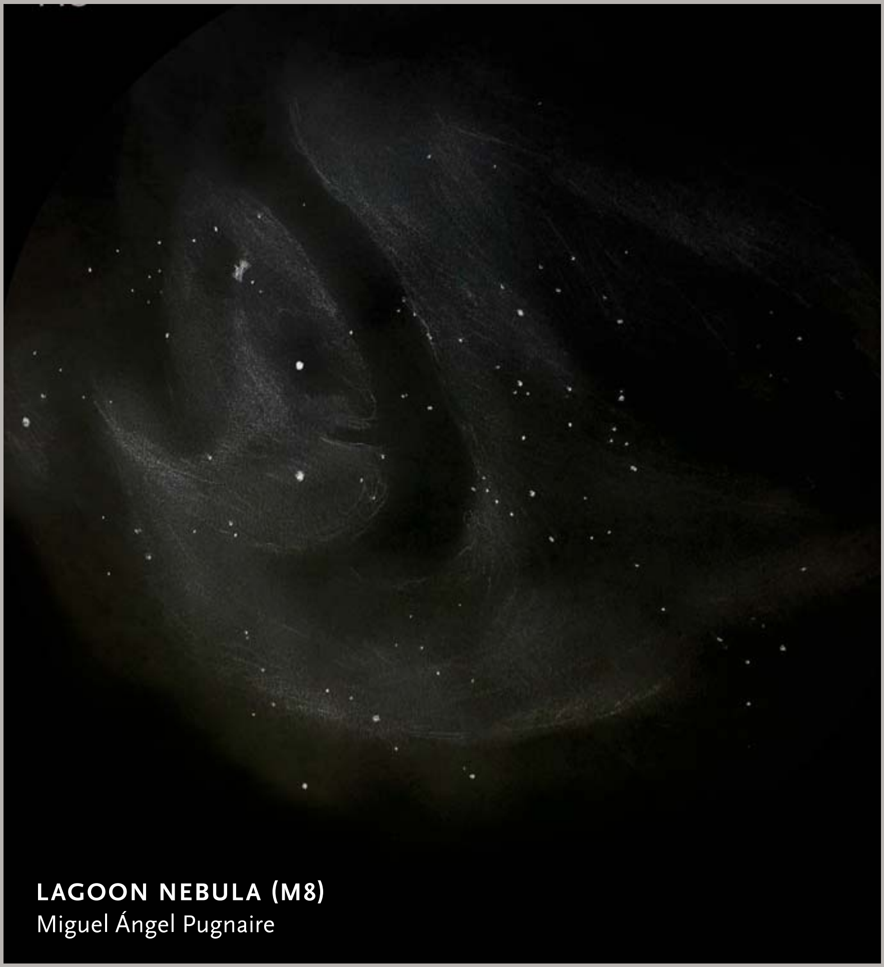




I can see *Cosmos* winning with two audiences in particular. First, space fans will begin drooling the moment they see the planetary diagram on the book's cover. Once they have *Cosmos* in hand, they'll likely lose all contact with other humans until they reach the last page — it's just that interesting. The second audience I see for the book consists of people in the business (and art) of science communication. Public affairs officers, science editors, and teachers will use this book as a primer on representing "unrepresentable" data to an audience. Even the infographics that (marginally) fail are instructive. In a few instances, the elegant aesthetic of the book worked against it. I would have preferred a bolder typeface in some sections, and the color-coding of chapters affected the legibility of a few diagrams. But I saw these moments less as problems and more as puzzles. If something didn't work for me, why not?

If you're even vaguely interested in space — what's out there, where it is, how large is it, and how does it work — I suggest picking up a copy of *Cosmos: The Infographic Book of Space*. You'll soon find that vague interest growing into something more intense, thanks to Lowe and North's thoughtful interpretations of the workings of our universe. ✦

S&T *Observing Editor* ***S. N. Johnson-Roehr*** *loves reading even more than she loves astronomy.*



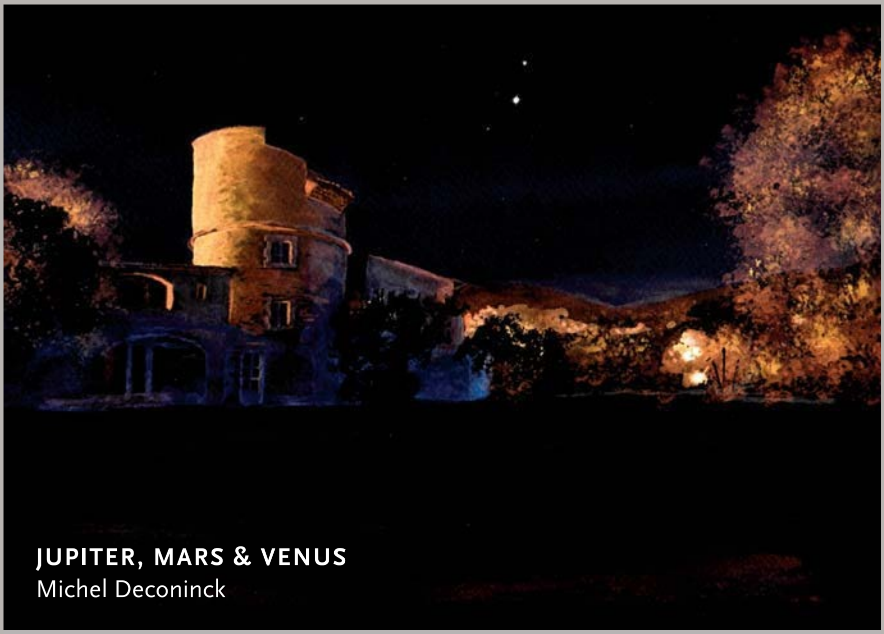
LAGOON NEBULA (M8)
Miguel Ángel Pugnaire

Celebrating Your Sketches

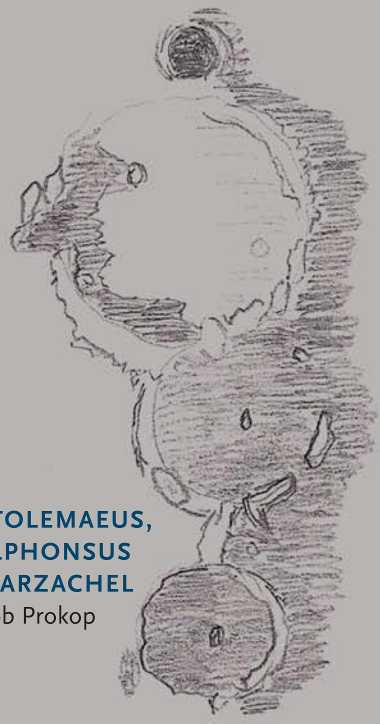
Most of us observe the night sky with the intent, at least in part, to try to gain some degree of intimacy with whatever we happen to be viewing. To preserve such sublime moments, some of us commit what we see to electronic imagery and others simply to memory.

But a growing number of amateur astronomers now practice the centuries-old tradition of sketching while at the eyepiece. Whether rendered as a few, quick strokes alongside observing notes or as a dedicated attempt to document every last tendril of nebulosity, sketching provides a way to record what you see using the simplest of means. Even better, sketching allows you to preserve a moment that is yours alone, a record of what *you* saw on that particular night, through that particular instrument.

The response to *Sky & Telescope*'s call for candidate sketches for Gallery has been impressive and gratifying. Displayed here are only a sample of the scores of beautiful renderings received. Enjoy them all!



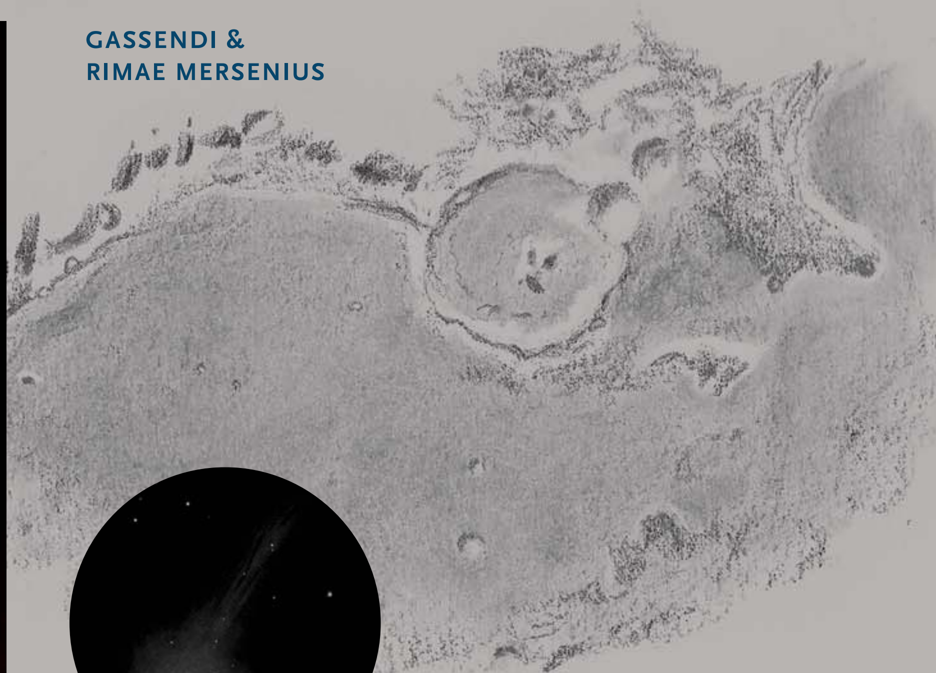
JUPITER, MARS & VENUS
Michel Deconinck



PTOLEMAEUS, ALPHONSUS & ARZACHEL
Bob Prokop

SOLAR PROMINENCES

GASSENDI & RIMAE MERSENIUS



COMET LOVEJOY (C/2014 Q2)

MOON & FIVE PLANETS

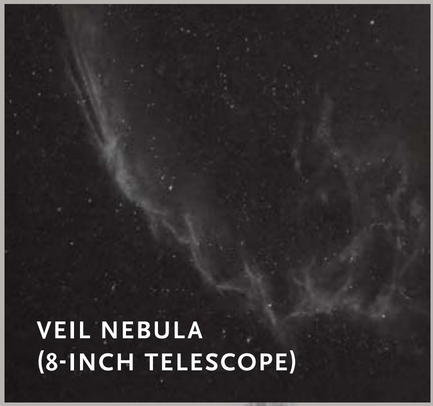
SCHICKARD TO FOURIER

CINDY KRACH • An animal surgeon and pet-care practitioner by day, Krach observes and sketches deep-sky objects nightly from her driveway in Kula, Maui. Her renderings came to the attention of the Astronomical League, and now she coordinates the League's recently inaugurated Sketching Observing Award (**http://is.gd/sketching_award**). Krach suggests checking out Astronomy Sketch of the Day (**www.asod.info**) and Cloudy Nights' sketching forum (**www.cloudynights.com/forum/81-sketching**).

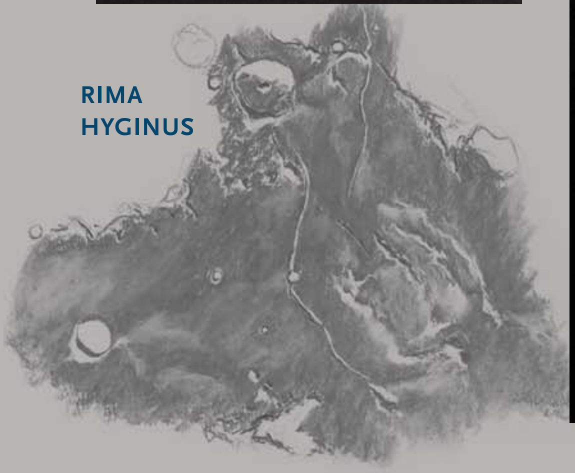
ALEXANDER MASSEY • Based in Maroubra, a suburb of Sydney, Australian amateur Alex Massey keeps busy with astronomy full-time. He's the owner of Gondwana Telescopes, building lightweight yet rugged Dobsonian reflectors. When night falls, Massey heads outdoors to revel in the southern sky's celestial riches. "Most people are seduced by the pretty pictures and want to create their own," he explains. "The main reason I started sketching was as a kid I didn't want to hit on my folks for the bucket loads of money that I realized, even back then, would be needed." Massey is indebted to the late Scott Mellish, who'd rediscovered the original means of astro-sketching prior to photography. Today Massey uses this "Mellish technique" to guide others through his blog (**alexanderastrosketching.blogspot.com.au**) and local workshops. And check out his excellent instructional video: **http://is.gd/Mellish_technique**.

GREAT NEBULA IN ORION (M42)

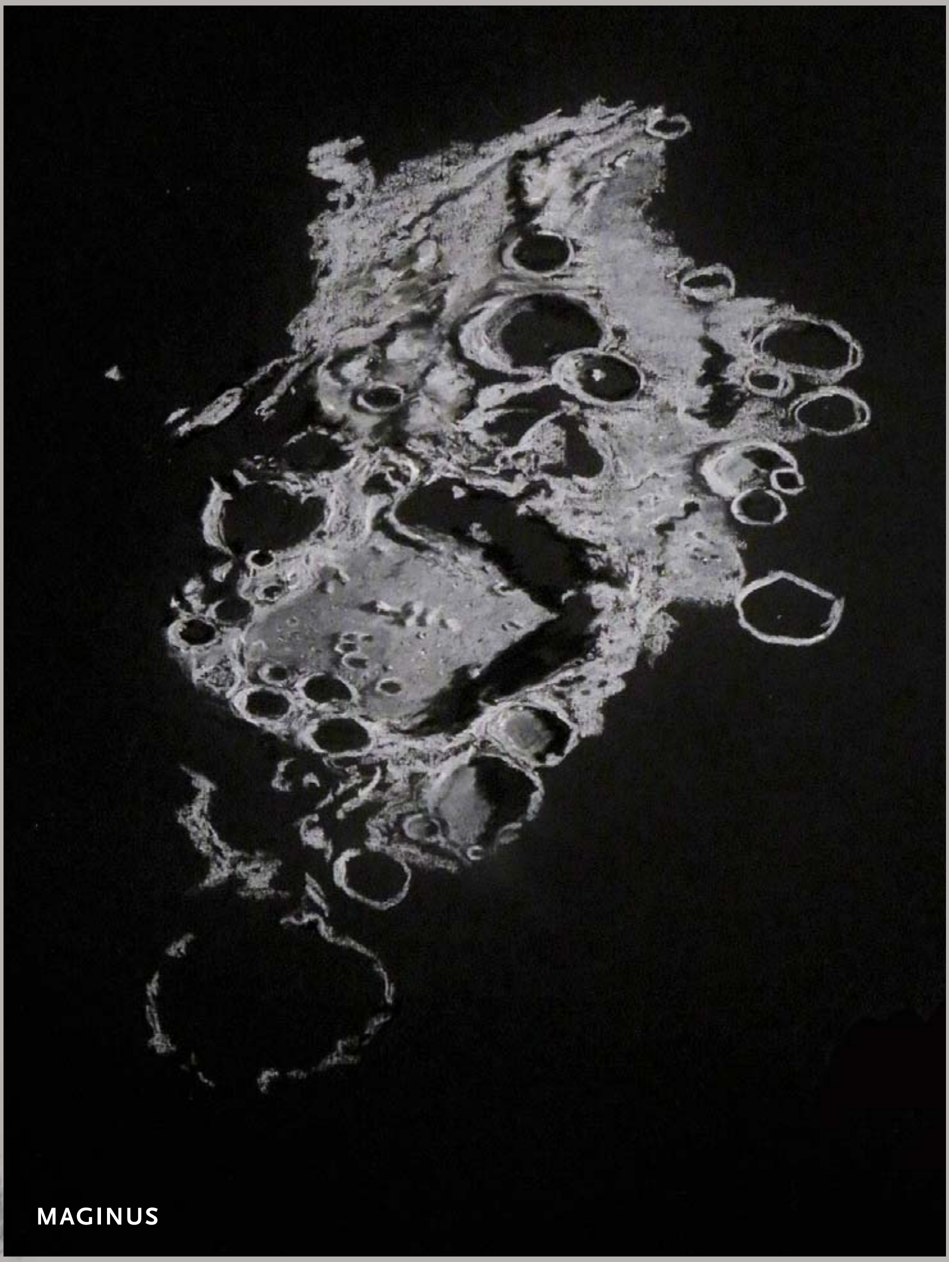
VEIL NEBULA (5-INCH TELESCOPE)



VEIL NEBULA (8-INCH TELESCOPE)

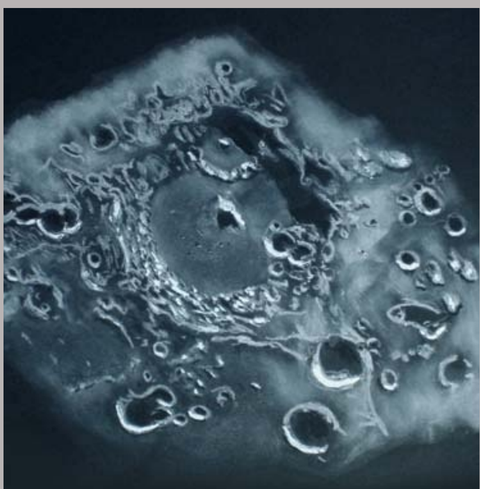


RIMA HYGINUS



MAGINUS

M35 OPEN CLUSTER
Doug Rennie



ALBATEGNIUS
Thomas McCague

COMET IKEYA-SEKI (C/1965 S1)
Donald W. Watts

PLEIADES (M45)
Kimberly Herman

MERSENIUS
Randolph Baron

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NASA / JPL

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After a 5-year flight, NASA's Juno spacecraft is set to orbit the King of Planets and to search for clues about the composition and structure of its deep interior.

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Getting Humans to Mars

Has this become inevitable, even imminent?

Ever since I was a kid, it's seemed like sending astronauts to Mars has always been 30 years away. Over the past half century, NASA and other agencies and organizations have commissioned dozens of studies about this grand goal, with landing dates variously between the 1970s and 2040s. Of course, none of those missions have come to pass (except in sci-fi movies). Recently, however, two big changes have, perhaps finally, made human missions to Mars not only practical but also possibly imminent.

The first is the widespread acceptance that visiting Mars in person is not just a fanciful idea but is actually *inevitable* in the near future. The scientific community has begun to align aspects of the ongoing robotic Mars survey program toward experiments and technologies that could directly benefit future human missions. Multiple Congresses and Presidential administrations have officially adopted human exploration of Mars as a major goal for NASA's near-term future. And judging from my experience talking with students, news media, and general audiences, the public has also accepted this idea. Average people are excited about robotic research but also realize that the biggest leaps in the scientific reconnaissance of Mars will need to be made by the men and women who go there and share their stories and discoveries with the rest of us back home.

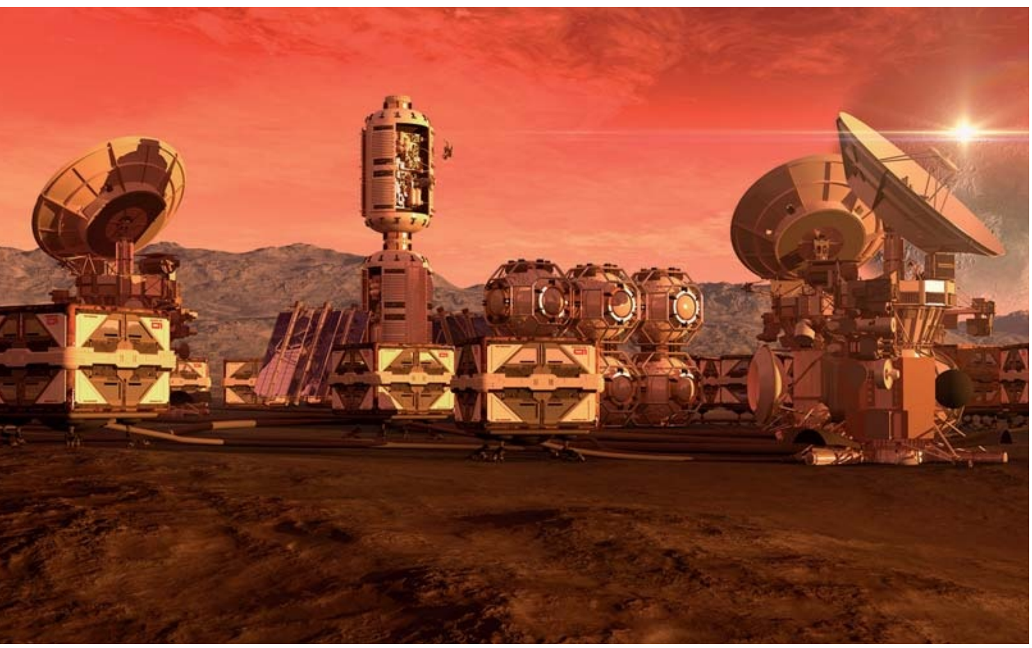
The second big change is the recent emergence of practical, affordable, and sustainable plans to begin to send astronauts to the Red Planet. This is not just for a short, one-off "flags-and-footsteps" mission. Rather it's part of a longer-term strategy to develop a scientific research outpost there and, perhaps, even a settlement.

The Planetary Society recently pitched one of these plans as part of its "Humans Orbiting Mars" initiative (**hom.planetary.org**). The proposal details how NASA's new Space Launch System rockets, Orion crew capsules, and Deep Space Habitation modules would first demonstrate the ability to get a crew to Mars orbit in the early 2030s. A series of Mars crew landings would follow starting in the late 2030s.

The basic premise of that plan, which can realistically fit within NASA's existing budget (if it keeps up with inflation), is similar to the logic behind the Apollo 8 mission: build missions incrementally, validating pieces like long interplanetary cruises and orbiting Mars first, then later add the complexities of landing and ascent.

Another of these plans, still in its infancy, comes courtesy of SpaceX and its visionary CEO Elon Musk. Musk's personal goal, and the driver behind all of SpaceX's rocketry and other research, is "enabling people to live on other planets" and specifically to begin the colonization of Mars. While the timeline for the company's Mars plans remains unclear, SpaceX has certainly shown an impressive, rapidly attained level of technical prowess and public interest. It might actually have the ability to send people to Mars in the late 2020s or early 2030s.

The huge popularity of the recent book and film *The Martian* is not a random occurrence. Rather it is a manifestation of an idea whose time has come. Dispatching people to Mars is no longer science fiction but instead a reality that will come true in the very near future. ✦



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Contributing Editor ***Jim Bell*** *is an astronomer at Arizona State University, author most recently of* The Interstellar Age, *and president of The Planetary Society.*