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THE ESSENTIAL GUIDE TO ASTRONOMY

SKY & TELESCOPE

JULY 2016

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Eta Carina. ProLine PL16803 & CFW-5-7. Telescope Design: Philipp Keller. Image: Chart32 Team. Image Processing: Wolfgang Promper.

SKY & TELESCOPE

July 2016 VOL. 132, NO. 1

On the cover: The Juno spacecraft arrives at Jupiter in July to study the giant planet's ins and outs.

JUPITER IMAGE: NASA / ESA / HUBBLE SPACE TELESCOPE
JUNO SPACECRAFT: NASA / JPL-CALTECH / EYES

FEATURES


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OBSERVING JULY

S&T TEST REPORT

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July 2016 Digital Extra

SKY & TELESCOPE

BONUS WEB CONTENT

- **Hercules Galaxy Cluster**
  Find here an expanded table of galaxies to accompany Steve Gottlieb's deep-sky column.
- **Hitomi Crippled**
  Read the full, updated story on what went wrong for Japan's X-ray satellite.
- **Join *S&T* in Iceland**
  Observing Editor JR Johnson-Roehr is excited to share the northern lights experience on our fourth annual trip.

Photo Gallery

Image by
Sergio Emilio Montúfar Codoñer

CHECK OUT OUR BLOGS!

- **Explore the Night**
  From the newest nova to overlooked wonders, follow Bob King as he investigates the mysteries awaiting us in the night sky.
- **Astronomy in Space**
  David Dickinson keeps up with the latest launches, mission proposals, and more.
- **Stargazer's Corner**
  Hear from our readers as they describe astro-adventures and offer observing advice.

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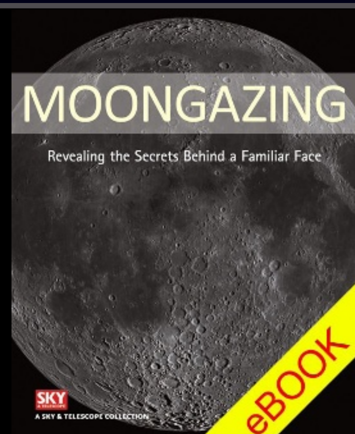

DIGITAL BACK ISSUES:
April, May, and June

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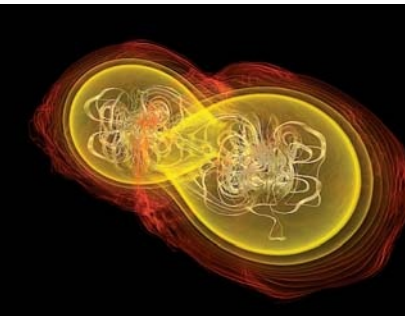
ONLINE PHOTO GALLERY

Over the course of two weeks in November 2014, photographer Brian Ottum collected 25 hours' worth of images to create this stunning three-panel mosaic of Andromeda Galaxy and its surroundings. "I had never done a big mosaic before," Ottum says a year and a half later, "so I did not have the courage to process until this week."

To the Unknowable

ASTRONOMERS TREASURE the idea of "unknown unknowns." These are astronomical objects and events that appear out of left field, totally new and unforeseen. An example is *fast radio bursts* (see page 24), about which we knew nothing before 2006. That year an undergraduate at West Virginia University, combing through hundreds of hours of archived radio data from Australia's Parkes Observatory, chanced upon the first recognized instance of these ultrabrief, super-bright flashes of radio waves.

There are "known knowns," or everything we've observed, studied, and think we understand. And there are "known unknowns," things we expect to uncover based on theory or hunch but haven't yet. Gravitational waves languished in this category for a century until LIGO detected them last September (*S&T:* May 2016, p. 10).



Do colliding neutron stars (simulated here) trigger fast radio bursts? One more deep-space enigma for us to tackle.

L. REZZOLLA (AEI) & M. KOPPITZ (AEI & ZUSE INSTITUTE BERLIN)

But the greatest potential for discovery, for knocking our socks off, comes with the unknown unknown. The lure of revealing the entirely novel, the wholly unexpected, is part of what drives the development of ever larger telescopes such as the Large Synoptic Survey Telescope and the Square Kilometer Array. These and other next-generation scopes will enable astronomers to probe previously unobservable swaths of the universe, identify new and exotic classes of objects, pick out that one-in-a-billion outlier or anomaly.

But there's a fourth category that most draws me, and perhaps many of you, to the mysteries of the universe: the unknowable. Chet Raymo phrases it well in his book *The Soul of the Night*, in which he describes his decades-long quest to find human meaning in the cosmos: "The pilgrimage is one that each of us must make alone, into the realm of the stars and galaxies, to the limits of the universe, to that boundary of space and time where the mind and heart encounter the ultimate mystery, the known unknowable."

We *know* we have questions about the universe and our place in it for which we may never secure answers. And a good thing, too: we need inexplicable phenomena to expand our minds and remind us that our cleverness has limits. Is our universe just part of a multiverse? Why does time exist? Why does *anything* exist? Do we matter?

Altogether, it's a firmament of inscrutabilities out there, and no matter how many we get to the bottom of, there will always be others that remain tantalizingly unfathomable. As H. L. Mencken once wrote, "Penetrating so many secrets, we cease to believe in the unknowable. But there it sits nevertheless, calmly licking its chops." ✦

Peter
Editor in Chief

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Sharp, bright, and in the right place at the right time. Just as we hope you will be on August 21, 2017. Oh, and good luck with that weather!


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at 2012/11/14 Cairns, Australia


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at 2016/03/08 in Indonesia

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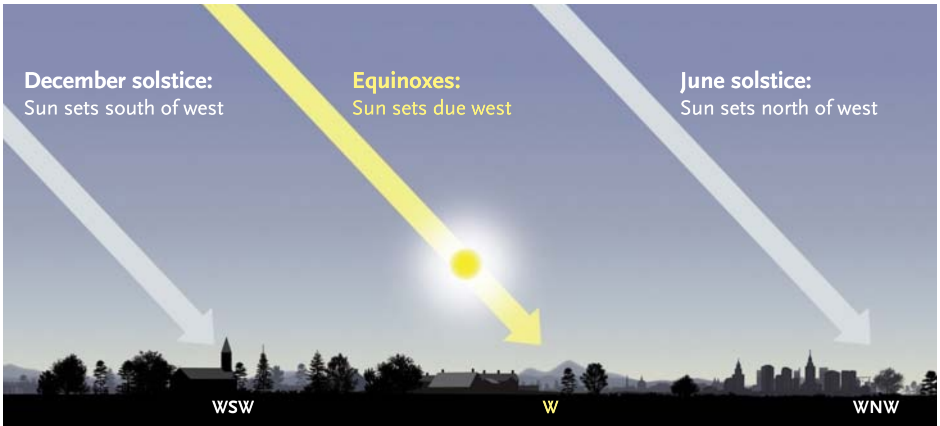

The Sun rises due east and sets due west on the equinoxes in March and September.

S&T: LEAH TISCIONE

An Equinox Sighting

This being a leap year, the equinox occurred quite early, on March 19th, at 11:30 p.m. Central Daylight Time — which I independently confirmed with a rather unusual method. I live on a rural line road, part of the vast grid of square-mile sections found throughout the Midwest. To the west, where my road meets the sky, trees on either side create a rectangular notch at the horizon — and thus a precise marker for the equinoxes.

On March 18th and 20th, the Sun sank below the horizon with about half of its diameter south and north of the notch, respectively. But at sunset on March 19th, I observed the last bright spark of sunlight precisely in my "Road Henge" notch — just four hours before the Sun crossed the celestial equator.

William Winchester
Collinsville, Oklahoma

Grasping Galactic Distances

Allow me to commend Ted Forte's "Galaxies in the Beehive" (*S&T:* Mar. 2016, p. 57). In addition to the usual observing data for the target objects — names, coordinates, magnitudes, and so on — his table also gives the *distances* to these various galaxies. That's surprisingly rare in similar *S&T* listings (after all, when observing celestial objects their distances usually don't matter).

Yet this is the information that offers a sense of the vastness of space surrounding us. For example, the galaxies NGC 2643 and 2647 look alike and insignificant in the image on page 58. The table, on the other hand, reveals that as the light from NGC 2647 passed NGC 2643 en route to Earth, it had already been traveling for more than 500 million years!

Raul Pettai
Montville, New Jersey

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

The Wrath of Juno

Who was responsible for naming the Juno spacecraft? What a lack of tact! She is the lawful wife of Jupiter. What will Juno think when she surprises him surrounded by Io, Europa, Ganymede, Callisto, and a lot of his other lovers? Juno's anger was proverbial. Perhaps on July 4th, when the orbiter finally gets there, we will see the most spectacular fireworks of our life!

Eduardo Vila Echagüe
Santiago, Chile

Kelly Beatty replies: *When Theodore Clarke proposed Juno as the name for NASA's Jupiter Polar Orbiter in 2003, he was keenly aware of the aptness of that suggestion. "The orbiter will maintain constant surveillance of the planet, constantly penetrating its cloud cover in search of its secrets," he wrote, "just as the mythological goddess Juno maintained constant vigil over her amorous husband-god Jupiter and his many lovers." Read all about the Juno mission and its objectives in Fran Bagenal's feature article, which begins on page 18.*

Remembering Marc Aaronson

Katherine Kornei's article on telescope operators (*S&T:* Mar. 2016, p. 22) rightly describes the value and skills of those workers. But the comment from TO Joel Aycock, "No lives will be lost," isn't strictly true. Astronomer Marc Aaronson died after a freak dome accident during an observing run at Kitt Peak's 4-meter Mayall telescope in 1987. The overall risk is far lower than in truly dangerous occupations such as soldier or lumberjack, but it isn't zero.

Steven Willner
Cambridge, Massachusetts

Rekindling the Awe

I completely agree with William Sheehan about the need for awe in our exploration of the universe (*S&T:* Mar. 2016, p. 84). I began studying astronomy in the 1960s and started leading expedition teams to observe grazing occultations. In those Apollo-era times I had no problem recruiting observers. We could go anywhere in the U.S., at any hour of the night, and were always welcomed by local citizens wanting to support our efforts in space.

Today it's very different. Few have interest in participating in an observation that requires effort, and the general population does not have any idea as to why we'd be out looking up at the sky. These days my telescope and I are more likely to be reported to law enforcement as an obvious terrorist setting up a rocket launcher! Our society needs to find its way forward to a new era in which we can go outside, look up at the sky, and once again see the awe that is in front of us.

Richard P. Wilds
Almond, New York

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I truly enjoyed William Sheehan's March Focal Point. It was marvelous and uplifting. He masters the gentle touch of imagery that blossoms into a world of wonders.

Melita Wade Thorpe
San Jose, California

Construction Zone Ahead

While the possibility of detecting an alien Dyson sphere would be incredibly exciting (*S&T:* Mar. 2016, p. 16), I have to take a step back and look at the possibility rationally. The light curve I've seen from the star KIC 8462852 indicates some obstructions blocking as much as 20% of the star's light, but most of the time 0% is blocked. Were some alien civilization to build such a structure as a Dyson sphere, would it really make sense to have sections many thousands of miles wide put in place while having most other sections not built at all?

I don't want to be a buzzkill, but it's hard to imagine these supposedly superior beings building such a structure in that haphazard manner. The most logical way would be to build a complete ring around the star first, and then make it broader and broader until the sphere was eventually complete. This would produce a light curve for KIC 8462852 that would be pretty much uniform (depending on its orientation relative to our line of sight) — not one exhibiting the stark fluctuations that have been observed to date.

Brian Cobb
El Cajon, California

Undersampled Exposures

I would like to add a little more to the advice on choosing a camera for astrophotography (*S&T:* Apr. 2016, p. 66). Richard S. Wright, Jr., notes that undersampled exposures can arise when the detector's pixels are too large for the telescope used. NASA came up with a process to improve the resolution of undersampled exposures from the Hubble Space Telescope called "drizzle" that's very effective and easy to do. You should have six or more exposures, taken with the telescope shifted very slightly (dithered) between each. The exposures should then be resampled by a factor of two — that is, resize a 500-by-500-pixel frame to 1,000 by 1,000 pixels before aligning and stacking. This allows you to shift the resized exposures by half the width of the original pixels and results in improved resolution. Note that this process only works with undersampled exposures.

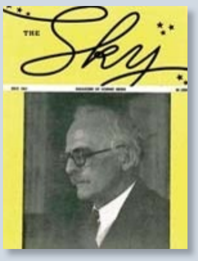
Ted Rafferty
Gaithersburg, Maryland

For the Record

✷ *The paired images of a rising Moon and Sun (*S&T: *May 2016, p. 74) were taken on September 27, 2015.*

75, 50 & 25 Years Ago

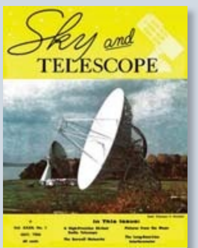
Roger W. Sinnott



July 1941

Nova Forecast "[At] the 30th annual spring meeting of the American Association of Variable Star Observers, at Vassar College, . . . Leon Campbell, recorder of the A.A.V.S.O., spoke on 'Do Ordinary Novae Repeat?' This question was answered in the possible affirmative by Russian astronomers in 1934. By plotting the range of magnitude of various well-known types of variables (particularly those which flare up at intervals, such as T Pyxidis, U Scorpii, and SS Cygni-type stars) against the logarithm of the period between outbursts, a curve is obtained on which ordinary novae may have a place. [Based on this relationship,] such novae as those in Aquila and Perseus may recur after an interval of 70,000 years."

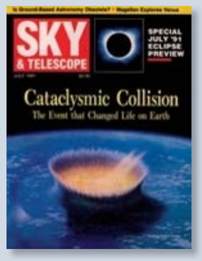
Nova Persei 1901 peaked at magnitude 0.2 and Nova Aquilae 1918 at magnitude –1.4. The speculation as to when they will erupt again is untestable, but astronomers now have a much better idea about what makes novae tick. Each is a binary star in which a white dwarf accretes hydrogen from its companion until a fusion reaction (as in a hydrogen bomb, only more gradual) takes place on the white dwarf's surface.



July 1966

Extragalactic X-rays "For the first time, X-radiation coming from the direction of individual galaxies has been measured. This is only one of several remarkable results reported by E. T. Byram, who with H. Friedman and T. A. Chubb has analyzed data from an Aerobee rocket in April, 1965. The flight was part of the U. S. Naval Research Laboratory's continuing program of X-ray astronomy. . . .

"To map the sky at wavelengths between 1 and about 15 angstroms, the Aerobee carried two Geiger counters, each behind a honeycomb baffle to limit its angular field of view. . . . X-rays were observed from the vicinities of two intense radio galaxies, Messier 87 (Virgo A) and Cygnus A. It appears that the X-ray emission from each is 10 to 100 times greater than the combined radio and optical emission. This result adds to the difficulty that theoretical astrophysicists have in explaining the enormous energy outflow from radio galaxies."



July 1991

Dinosaurs' Doom "In its heyday Chicxulub [on the northern coast of the Yucatán peninsula] thrived on the cultivation and export of sisal fiber. . . .

Unbeknown to its residents, Chicxulub (a Maya phrase for 'horns of the devil') has again become a mecca of sorts — but for geologists. A growing number of them suspect that a huge impact crater lies directly below it, buried far from sight by a thick layer of limestone sediment. But this would be no ordinary crater. If early indications prove correct, it is the Holy Grail of impact geology — the long-sought site of the blast that triggered the eradication of most life on Earth 65 million years ago.

Geologists have been combing the Earth for such a crater since 1980. That year a research team at the University of California, Berkeley, proposed that an asteroid's devastating arrival created the abrupt [geochemical] boundary found worldwide between the Cretaceous and Tertiary geologic periods."

Senior Editor Kelly Beatty, who followed this unfolding story closely, went on to tell how an Arizona graduate student, a Texas reporter, Mexico's national oil company, and a three-decade-old gravity map all played a role in finding the sunken, 180-km-wide crater.

Image by Christian García

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The Atik One conforms to the same high standards demanded in our scientific camera platforms and boasts the same industrial reliability. A cooling delta of 38 degrees below ambient temperature provides consistent, high-performance cooling whatever the weather, and argon purging of the CCD chamber ensures your sensor remains condensation-free.

Best of all, you can choose the Atik One as an Integrated Kit, complete with its own dedicated off-axis guider and Atik GP guide camera. The OAG features our renowned smooth focusing system and moveable prism, which takes the hassle out of finding and focusing your guide star.

All of this is connected through the camera's internal USB hub and accessory power port, giving you everything you need to take long exposure photographs of the deep sky, all in the One.

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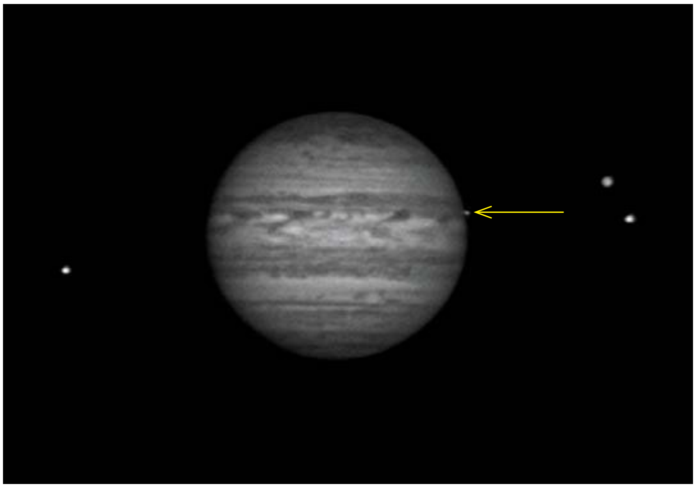
SOLAR SYSTEM | Impact on Jupiter?



JOHN MCKEON AND MARC DELCROIX

A frame from Irish astro-imager John McKeon's video of Jupiter taken March 17, 2016. He captured a momentary impact, lasting just 1 second, as a bright spot on the planet's limb. The moon Europa is at left; Ganymede and Io are at right.

Something seems to have hit our solar system's largest planet. Two amateur videos shot early on March 17th show a brief but bright flash on the edge of Jupiter's disk. Gerrit Kernbauer of Mödling, Austria, first called attention to the collision. He had recorded Jupiter using an 8-inch f/5 reflector in so-so seeing. But while reviewing his video 10 days later, he noticed a bright spot on one edge of the planet's disk that lasted for about 1 second.

Two days later, Irish observer John McKeon posted a second record of the flash. McKeon had used an 11-inch Schmidt-Cassegrain telescope and ASI120MM camera in Swords, a Dublin suburb. Crucially, he also used a near-infrared filter to reduce the planet's brightness. He was making a 3½-hour-long time-lapse video of Jupiter and its moons, "with a happy coincidence of the impact in the second-to-last capture of the night."

Soon planetary imaging specialist Marc Delcroix obtained the raw videos, processed them to bring out extra detail, and refined the circumstances of the flash. He finds that the brightening lasted just over 1 second and occurred at 281.1° in longitude and +12.4° in latitude (in System II coordinates, which apply to cloud features away from the equator). But the timing is off a bit: in Kernbauer's video the flash began at 0:18:35 Universal Time, whereas in McKeon's the onset is 9 seconds later.

Despite the time mismatch, the event appears to be real. Apparently the impacting object, be it an asteroid or comet, was rather small. "Nobody sees any debris field associated with that part of the atmosphere," notes planetary scientist Glenn Orton (Jet Propulsion Laboratory).

Apart from Comet Shoemaker-Levy 9's historic multiple-hit crash in 1994, the most obvious impact observed on Jupiter took place July 19, 2009, and it left a distinctly dark "powder burn" in Jupiter's upper atmosphere, first spotted by Australian astro-imager Anthony Wesley (*S&T:* Nov. 2009, p. 34). That was followed by three lesser strikes witnessed on June 3 and August 10, 2010, and on September 10, 2012. If evidence for March 17th's impact holds up (which is likely), then it'll be the fifth such event recorded in the past decade.

The reported sightings are likely only a fraction of the full number of hits the gas giant endures. In fact, we should be seeing impacts on Jupiter rather often, according to a statistical analysis published in the December 2013 issue of *Astronomy & Astrophysics*. Ricardo Hueso (University of the Basque Country, Spain) and his colleagues estimate that objects with diameters of 5 to 20 meters, as the last decade's impactors likely were, should collide with Jupiter anywhere from one to five times *per month*. If so, scores have gone unseen.

■ **J. KELLY BEATTY**

MISSIONS | European-Russian ExoMars Heads to Red Planet

The ExoMars Trace Gas Orbiter and Schiaparelli lander left Earth on March 14th aboard a Russian Proton rocket launched from the Baikonur Cosmodrome. A collaboration between the European Space Agency and Roscosmos (the Russian space agency), ExoMars will spend seven months cruising to the Red Planet. Then, on October 16th, Schiaparelli will decouple from the orbiter, touching down three days later at Meridiani Planum, the same region being explored by NASA's long-lived Opportunity rover, just as the spacecraft enters orbit.

The battery-powered lander is only expected to last four Martian days on the surface. A successful touchdown would represent a first for any space agency other than NASA and the Soviet Union (its Mars 3 stopped working seconds after arrival). Schiaparelli will test entry and landing technology for the European-Russian 2018 ExoMars rover.

Meanwhile, once it begins science operations at the end of 2017, the orbiter will search out evidence for trace gases in the Martian atmosphere. One elusive mystery on Mars is the source of methane, spotted both from Earth and by NASA's Curiosity rover. ESA and Roscosmos also plan to use the orbiter as a communications relay for the 2018 rover.

■ **DAVID DICKINSON**

MISSIONS | Kepler Spacecraft Recovered — Again

Kepler, the spacecraft with nine lives, burned through another life when it unexpectedly entered emergency mode in early April. It was fine on April 4th, when the team checked in as it ramped up for a special observing campaign that would flip the spacecraft around to look in a new direction. But when the team next contacted the craft on April 7th — 14 hours before any maneuvers began — it realized Kepler had shut itself down to the lowest possible level of operations.

The emergency status was also a concern because it drives the spacecraft to burn excess fuel to stay turned toward Earth for communication. But after a long weekend, the Kepler team recovered control and returned the spacecraft to operating in its lowest fuel-burning mode.

As of late April, engineers weren't sure what set off the series of false alarms that shut down the system. However, they have ruled out both the maneuvers and the craft's orientation-adjusting reaction wheels as the cause.

The failure of two reaction wheels (the first in July 2012, the second in May 2013) ended Kepler's primary mission, which had it intensely staring at a section of sky in Cygnus and Lyra to detect exoplanets. The current mission, called K2, balances the radiation pressure from sunlight with the spacecraft's thrusters and its two remaining reaction wheels to point at targets along the ecliptic plane in roughly 80-day observing periods. Already, K2 has found 270 planet candidates and 30 confirmed planets, and it's also observed open star clusters, measured starquakes and other stellar rumblings, and searched for supernovae.

In Campaign 9, which began two weeks late on April 22nd and will last through July 1st, the spacecraft changes from pointing away from Earth along our local spiral arm to gazing past our planet toward the galactic center instead. By flipping around, Kepler will aim at our galaxy's busy downtown to look for the short, sharp brightening of a faraway star as a free-floating exoplanet moves in front of it, in what's called a *microlensing event*. Augmented by ground-based observations and the Spitzer Space Telescope, Kepler will hopefully spot and characterize five or ten "rogue planets" during the campaign. Find updates at **http://is.gd/k2emergency**.

■ **MONICA YOUNG**

EXOPLANETS | Hot Days, Hotter Nights on 55 Cancri e

A new thermal map of the super-Earth 55 Cancri e (recently named Janssen) is puzzling astronomers.

Brice-Olivier Demory (Cavendish Laboratory, UK) and colleagues used the Spitzer Space Telescope as night-vision goggles, taking thermal images of the planet as it spun around its host star. The exoplanet is tidally locked, the same side always facing the stellar fire. While 55 Cancri e's nightside is hot (1400K, or 2000°F), its dayside is even hotter: 2700K (4400°F).

What's interesting is the large difference between the two hemispheres. Either this planet has no atmosphere at all, or its atmosphere is curiously bad at recirculating heat, the team reports March 30th in the journal *Nature*.

Add to this conundrum that the hottest point on the planet is not directly in the middle of the star-facing side; it's shifted some 40°. That's a big shift for a non-circulating atmosphere. We might instead be seeing a magma flow on the planet's surface. (Demory's team has previously suggested volcanism could explain a heat spike observed on this world.)

But Angelos Tsiaras (University College London) and others recently detected an atmosphere dominated by light elements, which would have no problem moving heat from one side to another (*S&T:* June 2016, p. 10). However, that work only sampled the topmost parts of the atmosphere, at the boundary between the hemispheres. So it's not yet clear if the observations contradict each other.

■ **MONICA YOUNG**

MISSIONS | Hitomi Crippled, Debris Seen

JAXA

Early on March 26th (Universal Time), the Japanese Aerospace Exploration Agency's newly launched Hitomi X-ray observatory (*S&T:* June 2016, p. 12) experienced a "communications anomaly." As of late April, engineers had still not reestablished a link to the crippled craft.

Hitomi failed to phone home during a routine ground station pass. At the time, the observatory was cooling down its sensitive instruments as part of a three-month checkout prior to full-scale observations. After the initial anomaly, the satellite sent three signals before falling silent.

The U.S. Joint Space Operations Center issued more bad news, as it tracked five pieces of debris related to Hitomi (the number later rose to 10). Soon after the crisis, backyard satellite watchers Ron Lee and Paul Maley estimated the craft was tumbling once every 5 seconds. On April 15th JAXA announced the anomaly's cause was a glitch in the attitude control system, which wrongly thought the spacecraft was rotating and tried to compensate, leading to out-of-control rotation that potentially sent parts — including the solar panels — flying off the craft.

An emergency action team is working to recover communication with the spacecraft. Find updates at **http://is.gd/hitomicrippled**.

■ **DAVID DICKINSON**

GALAXIES | Rare Super Spirals Discovered

SDSS

The super spiral designated 2MASX J16014061+2718161 is the brightest galaxy in a galaxy cluster and appears here with other disk galaxy companions (smaller blue smudges).

Astronomers have identified 53 "super spirals" — spiral galaxies that are huge and incredibly luminous — as part of a project exploring archived observations.

Across the cosmos the biggest, brightest galaxies are usually not spirals but ellipticals, gargantuan football-shaped collections of old stars. But Patrick Ogle (Caltech) and his team have found distant spirals that are bigger, brighter, and starbirthing-mightier than expected from their nearby brethren. These newfound galaxies, which the team calls superlumious spirals or "super spirals" for short, have disks between 180,000 and 440,000 light-years wide, and they're churning out stars at a rate of 5 to 65 solar masses each year. For comparison, the Milky Way's disk spans roughly 100,000 light-years, and each year it produces merely the equivalent of one Sun's mass in new stars.

Team members sorted through the NASA/IPAC Extragalactic Database to see what kind of big-picture insights they could glean from its archive. They picked out 1,616 galaxies with redshifts less than 0.3 (meaning the light we see left them less than 3.5 billion years ago) and luminosities more than eight times that of the Milky Way. Through a process of "how much/what kind of data do we have on this galaxy" elimination, the team whittled down the group of bright galaxies to a couple hundred and discovered that, although most were ellipticals, 53 were super spirals.

Given the small number found, these giants are clearly rare. Astronomers don't know how they're created. Four of the 53 galaxies look like they're midway through merging with another galaxy, and at least 10 seem to be in clusters or groups. But the others look fairly isolated. So it's unclear if super spirals form via mergers or via cosmic pipelines of cold gas that would feed the growing disk from the inside out (*S&T:* Sept. 2015, p. 16). Astronomers will need to study how star formation and neutral gas are distributed in the spirals in order to narrow in on the origins, the team suggests in the February 1st *Astrophysical Journal.*

It's curious that the galaxies are forming so many stars so recently in cosmic history. Galaxies this massive would normally be well on the way to becoming "red and dead." Somehow, super spirals managed not to choke off or heat up the cold gas supplies they need in order to make stars.

■ **CAMILLE M. CARLISLE**

IN BRIEF

Navy Resumes Celestial Navigation Course. In response to modern security threats, the U.S. Naval Academy in Annapolis, Maryland, has resumed training officers in the lost art of celestial navigation. Although this training used to be required, the advent of GPS technology led the Navy ROTC to end it in 2000, and the academy phased it out as well in 2006. But commercial GPS jammers are now readily available on the internet — and attacks, space debris, or solar storms could knock out GPS satellites. So the academy brought back celestial-navigation theory for its 2015 summer session. The class of 2017 will be the first in more than a decade with basic instruction in "shooting the stars."

■ **DAVID DICKINSON**

Hubble Finds Most Distant Galaxy Yet. Astronomers have found a humdinger of a galaxy dubbed GN-z11, which dwells in a universe just 400 million years old (in astrospeak, at a redshift, *z,* of 11.1, which refers to how much the universe's expansion has shifted the galaxy's spectra). The previous record holder was MACS0647-JD at 435 million years after the Big Bang ($z = 10.7$), but its redshift is not as precisely measured. Although the universe didn't start forming stars until it was about 100 million years old, GN-z11 already holds a billion Suns' worth of mass in its stars. It's churning out even more at a rate between 14 and 34 solar masses per year. Thanks to all those suns, GN-z11 is incredibly luminous, radiating three times the amount of ultraviolet light typical of galaxies in this early era, Pascal Oesch (Yale) and others report in the March 10th *Astrophysical Journal.*

■ **MONICA YOUNG**

Planet in the Hyades. Professional and amateur astronomers perusing K2 observations have found a young, Neptune-size planet in the Hyades open cluster. What's interesting about the world, called K2-25b, is its size: 10% the width of its parent star, a spotty, red *M* dwarf. No other planet has been found around an *M* dwarf that's so comparably large, Andrew Mann (University of Texas at Austin) and colleagues report in the February 10th *Astrophysical Journal.* The planet might be puffed up and losing its primordial atmosphere due to the radiation pouring out of the young, active star, which is 650 to 800 million years old. Astronomers will need two pieces of information to check this theory: the planet's mass (instruments that could detect it are now coming online, Mann says), and whether planets in other young systems are also abnormally large. The repurposed Kepler spacecraft has also observed the Pleiades and Praesepe (a.k.a. Beehive) open clusters, so hopefully more worlds will turn up in the data.

■ **CAMILLE M. CARLISLE**

TECH | Flood Threatens Photographic Plates

On the morning of January 18th, a burst pipe flooded Harvard College's Observatory Hill, submerging thousands of historic photographic plates underwater. Recovery efforts will take about 18 months.

The plates — 500,000 of them — crowd three stories of shelves in Building D of the Harvard College Observatory in Cambridge, Massachusetts. These glass film negatives were taken by astronomers both at Harvard and at outposts around the world over the years 1885 to 1992. The observatory stored them here as a large-scale celestial record-keeping project.

At about 5:30 a.m. that morning, the water main running beneath Observatory Hill ruptured. With 60 pounds of pressure, the burst 8-inch pipe was like "a fire hydrant on steroids," laments astronomer Jonathan Grindlay (Harvard), who directs the project to digitize the plates, called Digital Access to a Sky Century at Harvard, or DASCH (*S&T:* May 2015, p. 20).

The water filled the basement beneath the stacks first. At 8:30 a.m., when DASCH staff discovered the flood, there were 2 feet of standing water in the archive's bottom story. By the time the water was turned off, it had soaked the four lowest shelves of plates in their paper envelopes. It also destroyed a half dozen computers and the commercial scanner the team was using to digitize the archive.

Harvard's Weissman Preservation Center arrived with a couple thousand plastic boxes designed to store valuable documents under threat. Over three days, staff and volunteers packed each box with plates and ferried it out in "a sort of human bucket brigade," Grindlay says. By Thursday afternoon they had evacuated some 61,000 plates in all, or 12% of the collection, each in its sopping paper envelope.

DASCH

Volunteers and staff evacuated the plates in "Rescubes," stacked up here ready for loading.

The roughly 2,000 boxes now sit in three semi-trailer freezer cars, like an astronomical cryogenics lab, to keep them from molding. Over the next year and a half, disaster recovery contractors will carefully thaw and photograph each plate by hand before removing the paper and gently cleaning the plate itself to preserve the photographic emulsion.

Grindlay says they're confident that they haven't lost the plates; they'll be able to clean and scan them and finish DASCH, which is only about a third done. The team should be able to complete the digitization project in early 2018.

■ **CAMILLE M. CARLISLE**

MILKY WAY | Stellar Shell in Galaxy's Halo

The motions of 13 stars in our galaxy's halo outline a shell-like structure, Emily Cunningham (University of California, Santa Cruz) and colleagues report in the March 20th *Astrophysical Journal*. The stars might be the remains of an ancient run-in with a dwarf galaxy.

The halo is the cloud of stars that surrounds the Milky Way's disk. These stars generally follow orbits that take them in and out of our galaxy's center, rather than around it in a circular motion like the stars in the spiral disk. But Cunningham's team found that these 13 halo suns seem to be part of a shell of stars that are piling up as they turn around in their in-and-out orbits.

If the shell interpretation is correct, then this turning point in the stars' orbits could mark what's left of a dwarf galaxy — or perhaps even a group of dwarfs — that fell into the Milky Way's gravitational grasp several billion years ago. Cosmological models do predict that shells like this should be out there, says James Bullock (University of California, Irvine).

The team is compiling a much larger sample in a project known as HALO7D, which will contain information on hundreds of halo stars and help them confirm whether this shell and other structures exist.

■ **MONICA YOUNG**

BLACK HOLES | Spin Gauged, Duo Confirmed

Astronomers have measured the spin of a supermassive black hole and provided evidence that the behemoth has a companion. Mauri Valtonen (University of Turku, Finland) and collaborators studied the quasar OJ 287, which has double-peaked outbursts roughly every 12 years. Astronomers have suspected that a smaller black hole orbiting the larger one could cause the flashes as it punches through the monster's accretion disk. If so, the smaller monster's orbit should precess at a rate that depends on the more massive black hole's spin rate.

Based on what the precession would have to be to explain the timing of previous outbursts, the team successfully predicted OJ 287's December 2015 flare. Given this result, the researchers announce in the March 10th *Astrophysical Journal Letters* that the heavyweight rotates at only one-third its maximum spin. That translates to a rotation speed of 48,000 km per second (107 million mph) at the event horizon, which has a radius of roughly 50 billion km (30 billion miles). Such a slow spin rate suggests that random mergers might have played an important role in the black hole's growth, or that OJ 287's jets might be tapping the spin energy and slowing the black hole's rotation. If the method holds up, it could be a novel way of calculating binary black holes' spin. ✦

■ **ALLEN ZEYHER**

The Golden Spike of Tranquility Base

A modest proposal: the Anthropocene began with the lunar landings.

A FAR-FUTURE GEOLOGIST studying Earth history would observe that our time was one of sudden and unprecedented planetary changes. Could this be a type of transition that other planets also go through, when cognitive systems begin to influence global systems?

I've written before about the proposal to formally rename our current geological epoch the Anthropocene (*S&T:* Apr. 2013, p. 16) to acknowledge the fact that humans have become a major force of global modification. Within geological and other academic circles it's been contentious but fruitful — sparking interesting debates about how we humans should regard, and attempt to guide, our own planet-altering presence.

There's no consensus over when exactly this humanized age began. Did it arise with the first atomic bomb explosions in the 1940s? If there was ever a time when we started to realize we were all in the same boat, shooting holes in the hull, it was the dawn of the nuclear age. We began to see what we'd become, and it left an indelible isotopic signature. This provides what geologists call a "golden spike," a unique time stamp associated with an event or transition. Others place the onset of the Anthropocene at the beginning of the Industrial Revolution, or thousands of years earlier when we first undertook large-scale modification of landscapes.

These arguments are most valuable if we read them as a protracted dialogue on how humanity has journeyed from being just another hominid species in East Africa to the global force we are today. I view them as a series of waypoints, each proposed origin marking a different stage in the "hominization" of the planet. Looked at in this way, there is no single, correct moment of genesis.

But if geologists are going to formalize the definition, they need to pin it to a specific stage in the rock record. So let me offer my own modest proposal for a "golden spike" to mark the Anthropocene. If we must choose one geological deposit that announces the human presence, I would suggest the area of Mare Tranquillitatis where Apollo astronauts first stepped onto another world, leaving a flag, machines, and footprints.

Those boot marks will fade in a few million years as micrometeorites grind them into the dust, but signs of our presence, including the alien artifacts we left, will be detectable for as long as there is an Earth and a Moon. These lunar landmarks could not have been made by a species without world-changing technology. This altered landscape also captures the moment we first looked back and saw the unity of our home and our common destiny with all life on our planet.

Of course, as an actual proposal for correlating geological events on Earth, a Tranquility Base golden spike is ridiculously impractical. But so what? There is nothing practical about the decision to formalize the Anthropocene Epoch. Any geologists, human or alien, studying our time millions of years from now will not care about our nomenclature. This is all about symbolism and our self-image as we confront the challenges of this new age. So, I know I'll lose but I vote for Tranquility Base. ✦

S&T: PATRICIA GILLIS-COPPOLA

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Revealing Jupiter's Inner Secrets

FRAN BAGENAL

NASA scientists hope their Juno orbiter will get the "inside story" on our solar system's largest planet.

Jupiter reigns supreme among the worlds of our solar system: it's the largest, most massive, fastest rotating, most strongly magnetized, and has the greatest number of known satellites (67). Moreover, Jupiter's importance extends far beyond the Sun's realm. It's the archetype for hundreds of similarly massive planets found around other stars.

Yet despite an exterior of pretty, swirling clouds that get all the public's attention, Jupiter harbors many secrets. Some of the prime issues of planetary science are hiding inside this planet. Does Jupiter have a core? How do the stirrings inside generate such a strong magnetic field? And perhaps the most important question: how much water lies hidden below those colorful clouds?

We took our first step to gain firsthand answers on December 7, 1995, when NASA's Galileo probe — a 339-kilogram, 1.3-meter-wide craft — hurtled into Jupiter's atmosphere at 48 km per second. Slowed by parachutes and protected by a heat shield, the probe and its seven scientific instruments measured the properties of the atmosphere for a little under an hour as the ensemble descended nearly 160 km to pressures exceeding 23 Earth atmospheres.

Everyone expected the probe to pass through three dense, distinct layers of clouds: ammonia (NH_3) at the top, ammonia hydrosulfide (NH_4SH) in the middle, and water clouds (H_2O) below. The temperatures, pressures, and winds recorded weren't far from scientists' predictions, but the big surprise was a lack of clouds — especially the water layer. Did the probe just hit a dry, cloudless spot? Or is there really much less water than expected? Jupiter's dry weather had enormous implications.

Why Care About Water?

Conventional thinking holds that the giant planets began as small grains of rock, metal, and ice. As they bumped into each other, the grains grew bigger — first to boulders and then to kilometer-sized planetesimals — eventually forming Earth-sized planetary embryos.

Since the giant planets formed beyond the "snow line,"

EARLIER EXPLORATIONS

Juno will be the 10th spacecraft to study Jupiter at close range. The others were: Pioneer 10 (1973), Pioneer 11 (1974), Voyagers 1 and 2 (1979), Ulysses (1992), Galileo probe and orbiter (1995–2003), Cassini (2000), and New Horizons (2007).

NASA / JPL

BIG AND BRAVE Three giant solar-cell panels, each 9 m (29½ feet) long, power NASA's Juno spacecraft. Once it begins orbiting Jupiter on July 4th, Juno will have a limited lifetime before its electronics absorb a lethal dose of high-energy charged particles.

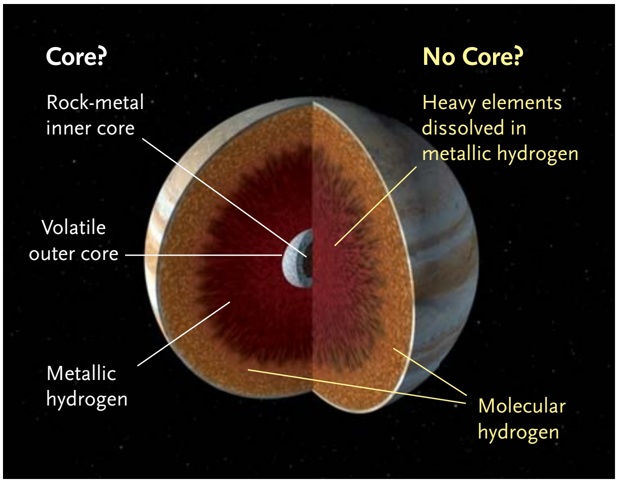
a hypothetical boundary in the primordial solar nebula beyond which water turned to ice, the snowball embryos could continue to grow until they reached 10 to 15 Earth masses. These became the cores of the giant planets.

Such large cores then had enough gravity to pull in the most volatile gases — mainly hydrogen, plus helium and neon — from the surrounding nebula. Most of Jupiter's 318-Earth-mass bulk comprises these light gases, with the remaining "heavy elements" — astrophysicists' shorthand for any atoms more massive than helium — dominated by oxygen, likely in the form of water.

Theoretical models give a range of Jupiter's combined heavy-element abundance, somewhere between 3% and 13% by mass. This is a huge uncertainty, and frankly to have up to 20 Earth masses of oxygen unaccounted for seems a bit of an embarrassment. Pinning down the Jovian water abundance has major compositional implications not just for Jupiter but also for all solar systems.

Befuddled by the Galileo probe's dry descent, planetary scientists initially clamored to have NASA send more probes into Jupiter's atmosphere to find out where the water could be hiding. Scott Bolton and colleagues at the Jet Propulsion Laboratory had a better idea. Microwaves are absorbed by water (that's how a mug of tea gets heated in a microwave oven), and Jupiter emits microwave radiation from its hot, deep interior. So, Bolton thought, why not just fly a microwave receiver above the clouds of Jupiter to map the distribution of water? Flying close enough to Jupiter to do that would also enable detailed mapping of the planet's gravitational and magnetic fields.

But there was a catch: the dense equatorial belt of



TAKE YOUR PICK Planetary scientists hope Juno will let them finally decide whether Jupiter has a solid core of metal, rock, and ice (left cutaway) or essentially no core at all (right cutaway).

energetic charged particles trapped in Jupiter's magnetic field. To sound Jupiter's interior, a spacecraft would need a polar orbit that ducks under the radiation belt as it skims above the atmosphere. Thus, the mission concept that became Juno was born.

In 2005 NASA managers selected Juno as the second mission in the space agency's New Frontiers program. Competing with other missions for NASA funding meant that the Juno scientists (led by Bolton, now at the Southwest Research Institute) had to limit their appetite and focus attention on three main objectives: Jupiter's interior, its atmosphere, and its polar magnetosphere.

Core: What's Stirring Inside?

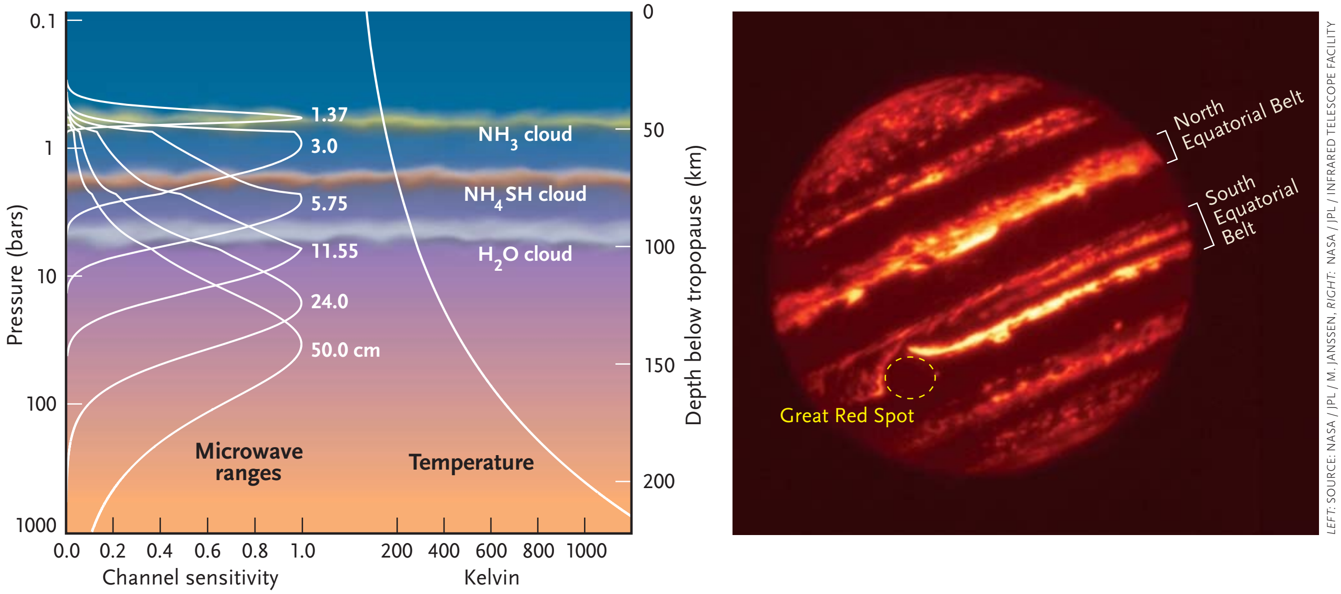
Despite close-up explorations of Jupiter by several previous spacecraft, the planet's interior remains a mystery. Not only do we not know what quantities of heavy elements it contains, we also don't know if these elements remain concentrated in a central, solid core.

For decades textbooks have shown Jupiter with a small central core of solid rock and ice and an outermost layer of molecular hydrogen. In the large, central volume in between, the pressure is sufficient to allow the protons and electrons of atomic hydrogen to move past each other freely, enabling strong electrical currents to flow. Circulating flows within this large volume of so-called *metallic hydrogen* give rise to the planet's strong magnetic field.

Jupiter has the second most powerful magnetic dynamo in the solar system (after the Sun's). It probably bears little more than superficial resemblance to the one operating in Earth's small, iron core, but is it necessarily like the Sun's dynamo?

Computer modeling can simulate swirling flows driven by primordial internal heat and wrapped up in Jupiter's rapid rotation (the planet's spin period is just shy of 10 hours). But such models depend on knowing how an unknown mix of hydrogen and heavy elements behaves at the ultrahigh pressures (some 50 million atmospheres), high temperatures (20,000 Kelvin — four times hotter than the Sun's photosphere), and high density (somewhere between those of rock and lead) present in the metallic-hydrogen layer.

Scientists gain insight into the properties of hydro-



THERMAL PROBE *Left:* By recording Jupiter's emissions at six microwave wavelength ranges, Juno will map the global abundances of water and ammonia in and below its three distinct cloud layers. *Right:* When viewed at the infrared wavelength of 5 microns, Jupiter's familiar belts and zones are replaced with a pattern of heat escaping from deep within its cloud layers. Astronomers Thomas Momary and Glenn Orton recorded this view on April 4, 2016.

gen compressed to such an extreme state by zapping it with lasers in laboratory experiments, as well as from sophisticated quantum-mechanical models. Recent studies suggest that the heavy elements could be completely dissolved in the metallic hydrogen and stirred up into a relatively uniform mixture. So, contrary to the standard textbook picture, Jupiter might not have a distinct core after all.

But these lab studies and computer models can only take us so far. Ultimately, our knowledge of Jupiter's interior will require three key measurements: (1) a determination of the bulk abundance of heavy elements, (2) mapping the planet's gravity field, and (3) mapping the planet's magnetic field. To achieve the necessary accuracy and spatial resolution, these measurements need to be made as close as possible to the planet.

Atmosphere: Where's the Water?

The surprisingly clear "hot spot" into which the Galileo probe plunged was so dry that, even at pressures four times greater than where we expected to encounter the water clouds, water was still greatly depleted. Images of Jupiter taken from Earth at the time of the Galileo probe's entry show that it dropped into a region between the cloud bands in what was apparently a fierce downdraft of dry gas from the upper atmosphere.

Sky & Telescope readers are familiar with Jupiter's white and tawny orange cloud bands and its enigmatic, slowly shrinking Great Red Spot (*S&T:* Mar. 2016, p. 18). Visible-light spectra show that the bright zones are clouds of ammonia droplets. But the coloring agent of the darker belts and the GRS has puzzled astronomers for many decades. Current thinking is that irradiation of atmospheric gases produces long-chain sulfur compounds that are mixed in with ammonium hydrosulfide.

When we view Jupiter at longer, infrared wavelengths, the energy we see is not light reflected from the Sun but instead emitted from hotter gases below the planet's upper cloud decks. This shows clearly in the 5-micron image at left (facing page): cold, high-altitude ammonia clouds look black, and the bright bands record infrared energy from deeper down that's escaping between the clouds. If we look at even longer wavelengths in the microwave region, we probe deeper into the atmosphere.

Juno's microwave radiometers (MWR) will record six bands at wavelengths from 1.37 to 50 cm, chosen to detect water down to pressures of at least 100 bars and to ensure that we obtain oxygen's elemental abundance. The MWR observations should also yield the abundance of nitrogen (derived from ammonia). These findings, added to results from the Galileo probe, will be crucial to understanding how Jupiter formed, how it acquired its atmosphere, and how it evolved over time.

While the radiometers map the abundance and distribution of materials below the clouds, the JunoCAM, UVS, and JIRAM instruments will make complementary observations of what's happening topside at visible, ultraviolet, and infrared wavelengths, respectively. Thanks to Juno's highly inclined orbit, we'll get our first pictures looking directly down on the poles of Jupiter. Does the alternating pattern of belts and zones persist all the way to the poles? We'll soon have the answer!

Magnetosphere: What Drives Jupiter's Intense Auroras?

Jupiter's powerful dynamo generates a huge magnetosphere — it's the largest object within the solar system. On the planet's sunward side, this magnetic bubble typically extends to distances of 3½ to 7 million km — 50 to 100 times Jupiter's radius. On the nightside, Jupiter's magnetotail stretches beyond the orbit of Saturn.

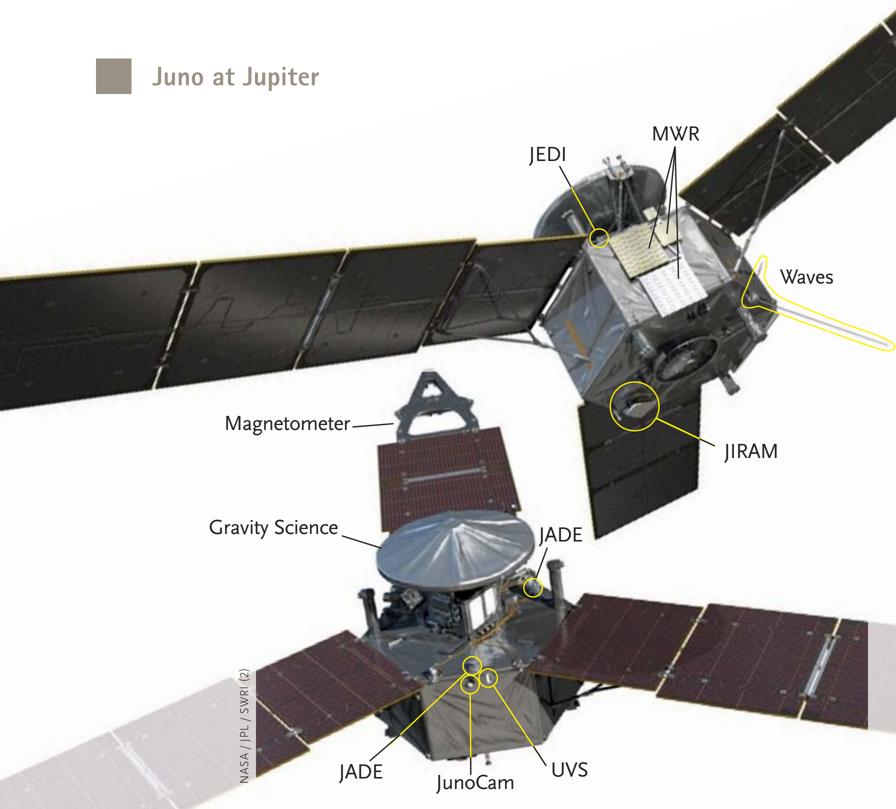
How Much Pressure?

A sense of pressure comes from the force of gravity you feel through the area of your feet due to the weight of your body. Stand on one foot and you halve the area, doubling the pressure. The pressure of the gas in the atmosphere you are breathing is equivalent to the force you'd experience through your feet with four people stacked on your shoulders. This seems unbelievable, but we're used to it. The pressures at the center of Jupiter are some 50 million times greater. That's like 1,000 elephants stacked up with the bottom elephant standing on one foot — and balancing on a stiletto heel!

S&T: LEAH TISCIONE

JunoCAM and You

Although taking pretty pictures isn't one of Juno's main goals, the team added JunoCAM to increase public involvement in the mission. Even better: you can vote on which pictures you want it to take. The JunoCAM website (**www.missionjuno.swri.edu/junocam**) also solicits images of Jupiter you've taken with your own telescope, and hundreds are already posted. These images will allow scientists studying Jupiter's cloud structures with Juno's instruments to get the context of those observations. What's happening in those cloud bands? Where are the dark spots? Where are the winds blowing strongest before, during, and after each Juno orbit?



SOPHISTICATED SCIENCE Juno's seven scientific instruments, combined with radio tracking to map Jupiter's gravity field and its ride-along imager, should answer many longstanding questions about the King of Planets.

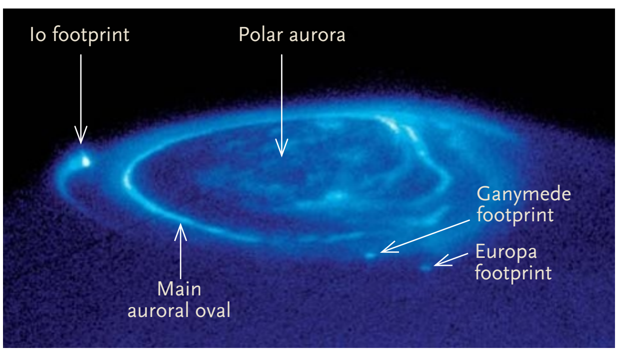
Astronomers first detected the magnetosphere of Jupiter in 1954, four years before Explorer 1's discovery of the Van Allen radiation belts around Earth, via bursts of radio emission. These early radio measurements showed that Jupiter has a strong magnetic field with an axis tilted about 10° from the spin axis and with a polarity opposite that of Earth's. The magnetosphere's most energetic electrons, pumped to more than a million electron volts (1 MeV), are trapped near the equator and close to the planet. These very energetic particles pose a formidable hazard for spacecraft exploring close to Jupiter.

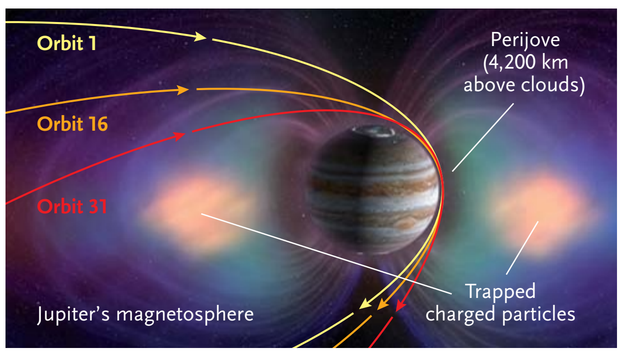
Ground-based radio observations in 1964 revealed that Io plays a peculiar role, in that the bursts of radio emission were modulated by the position of this moon along its 42-hour orbit around Jupiter. When Pioneers 10 and 11 flew past Jupiter in the mid-1970s, their magnetometers and particle detectors revealed the vastness of Jupiter's magnetosphere and made direct measurements of energetic ions and electrons. But we didn't understand Io's role until another spacecraft's brief visit in 1979.

That's when Voyager 1 revealed Io's prodigious volcanic activity and found that more than 1 ton of sulfur dioxide (SO_2) escapes from this moon's tenuous atmosphere per second. These neutral molecules are soon dissociated into sulfur and oxygen atoms, which in turn become ionized and trapped by the magnetic field. The resulting torus of plasma — a huge doughnut of charged particles — roughly co-rotates with Jupiter's 10-hour spin period. The ions of sulfur and oxygen become excited during their frequent collisions with the magnetosphere's trapped electrons, and consequently they radiate about 1½ terawatts of ultraviolet energy.

This plasma couples to Jupiter's rotating atmosphere (specifically, to its ionosphere) via electric currents, and this coupling dominates the dynamics of the magnetosphere. One consequence is that energetic electrons bombard hydrogen molecules in the upper atmosphere, triggering intense auroral emissions that span the spectrum from X-ray to radio wavelengths.

Dramatic images from the Hubble Space Telescope's ultraviolet cameras show that Jupiter's intense auroras are constantly active. Meanwhile, ground-based observations of infrared emissions from the unusual molecular ion H_3^+ have revealed an auroral spot at the foot of the magnetic field lines connected to Io. Aha! This Jupiter-Io connection must be the source of the radio bursts that astronomers have been monitoring all these decades. Hubble images also show auroral spots associated with Europa and Gany-





LIGHT SHOW *Left:* The complex auroras at Jupiter's north pole stand out clearly in this ultraviolet image obtained with the Hubble Space Telescope's Imaging Spectrograph (STIS) on November 26, 1998. Auroral "hot spots" mark where electric currents magnetically tied to Io, Europa, and Ganymede intersect the planet's upper atmosphere. *Right:* Juno's orbit is the key to this mission's success. By moving in a highly eccentric polar orbit, the spacecraft minimizes its exposure to high-energy charged particles yet gets near enough to study the planet at close range. But orbital precession due to Jupiter's gravity will eventually drag the orbit through those intense radiation zones, dooming the spacecraft.

mede, indicating further electrical current systems.

These various auroral emissions tell us that beams of energetic electrons and ions are shooting into Jupiter's atmosphere. We suspect that these charged particles become accelerated via processes like those involved with Earth's auroras. Yet despite seven flyby spacecraft and Galileo's 33 orbits around Jupiter, no spacecraft has yet flown directly over Jupiter's poles.

So Juno's scientists and engineers loaded the spacecraft with instruments that can measure charged particles, magnetic fields, and electric waves as it flies for the first time through the magnetic field lines where we think the auroral particles are generated. At the same time, UVS, JIRAM, and JunoCAM will look down on the auroras where those same field lines intersect the planet.

I must admit that I'm a bit nervous for Juno — those field lines carry millions of amps of electrical current. It's a scary place to explore.

Juno's Imminent Arrival

For the first time, we have sent a spacecraft to the outer solar system that's not powered by the radioactive decay of plutonium. Instead, Juno generates electricity via three huge solar-cell panels, each 9 m (29½ feet) long. At Jupiter, where sunlight has 1⁄25 its intensity at Earth, these panels generate 400 watts of power. Roughly half of this keeps the spacecraft warm, while the rest powers Juno's electronics, radio transmitter, and science instruments. The spacecraft slowly cartwheels, once every 30 seconds. That's a plus for gathering charged-particle and electromagnetic data, but even this slow rotation makes snapping pictures tricky.

Juno rode an Atlas V rocket into space on August 5, 2011. After using a gravity boost from a flyby of Earth in October 2013, Juno will finally arrive at Jupiter on July 4th. Firing its main engine for 30 minutes when at its closest to the planet, the spacecraft will slow enough to achieve a polar orbit. The first couple of orbits are planned to last 53 days each, allowing the Juno team to get used to operating the spacecraft at Jupiter.

Then, in mid-October, more engine firings will drop Juno into a sequence of 14-day-long orbits. During each of these, the spacecraft will make a 2-hour dash over the north pole, duck under the potent radiation belt as it speeds (at 60 km per second) just 4,200 km above the cloudtops, and then zoom back out over the south pole. For the rest of each elliptical circuit, which will carry the spacecraft out to about 2.7 million km, Juno will transmit the data gathered during its most recent close-in dash and sample the magnetospheric environment far from the planet.

Such an orbit would be just great if we could keep it that way. But Jupiter's 10-hour rotation makes its equator 6% fatter than the poles. The bulge's gravity will constantly tug on the spacecraft, altering its trajectory and precessing (tilting) the orbit by about 1° per circuit. Sooner or later Juno will plunge through the equatorial radiation belt. We've protected the electronics as best we can by encasing them in a titanium vault. But quite likely bathing those sensitive electronics in 10 MeV electrons will cause damage. We're hoping for 35 orbits — even a handful would revolutionize our understanding of Jupiter — and, who knows, perhaps the spacecraft will survive much longer.

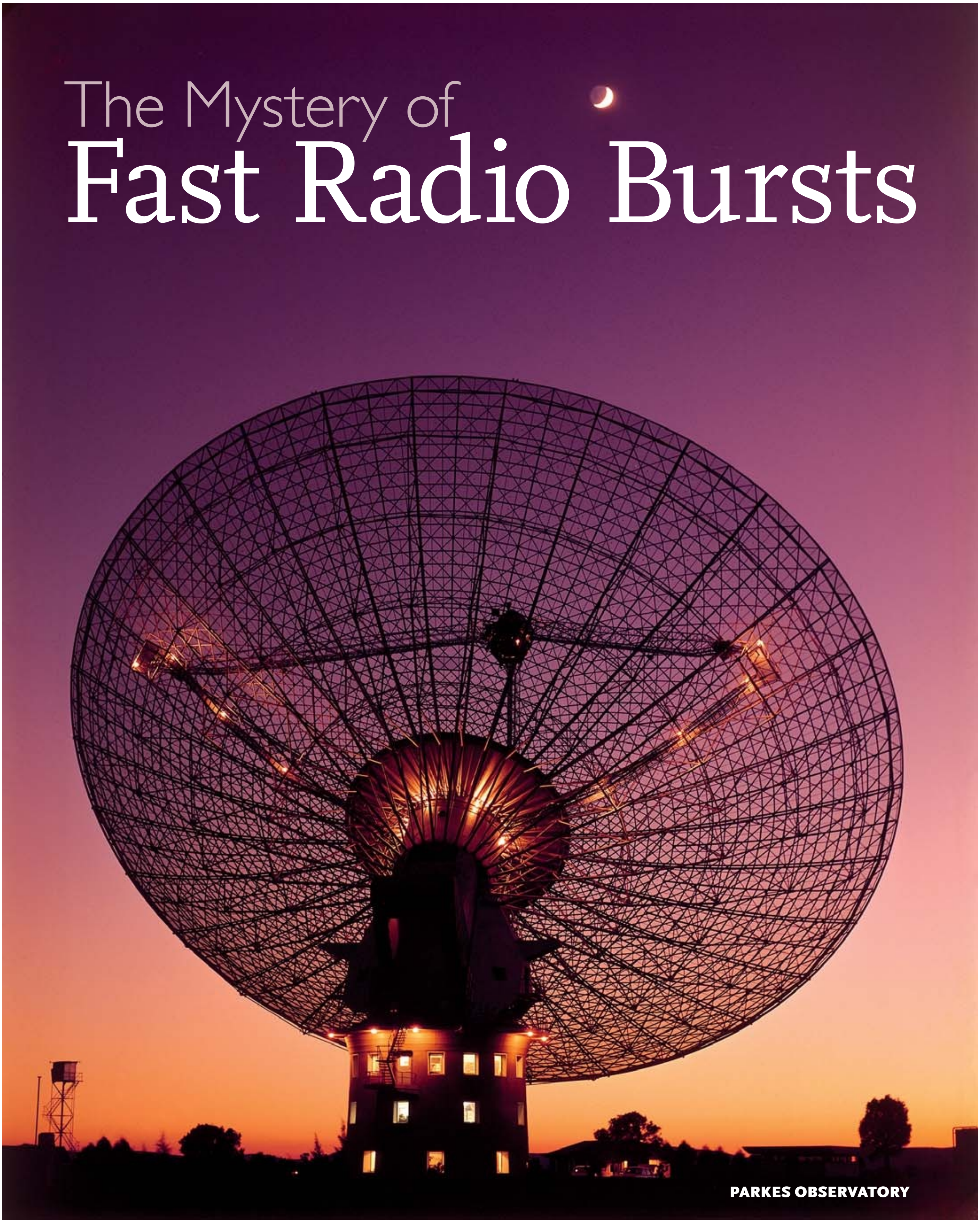
Get ready, Juno — the fun's about to begin! ✦

Scientific Investigations on the Juno Spacecraft

Instrument	Acronym	Description
Gravity Science	GS	Detects Doppler shift of radio broadcasts from Juno to Earth to derive small motions of Juno due to Jupiter's uneven gravity field and its internal mass distribution.
Jovian Auroral Distribution Experiment	JADE	Measures the distribution, energy, and velocity of ions (5 eV to 50 KeV) and electrons (100 eV to 100 KeV) in auroral regions of Jupiter.
Jovian Energetic Particle Detector	JEDI	Measures fluxes of high-energy ions (20 keV to 1,000 keV) and electrons (40 keV to 500 keV) in the polar magnetosphere of Jupiter.
Jovian Infrared Auroral Mapper	JIRAM	Maps upper layers of the atmosphere (2 μ to 5 μ) to depths of 50 to 70 km (5 to 7 bars); images auroras at 3.4 μ (H_3^+ ions); detects CH_4, H_2O, NH_3, PH_3.
JunoCAM		Visible-light telescopic camera to facilitate education and public outreach.
Magnetometer	MAG	Measures the strength and direction of the magnetic field; Advanced Stellar Compass (ASC) monitors orientation of MAG sensors.
Microwave Radiometers	MWR	Measures electromagnetic waves in six ranges (600 MHz to 22 GHz) to map H_2O and NH_3 abundances to pressures of up to 200 bars (depths of 500 to 600 km).
Ultraviolet Spectrometer	UVS	1024-by-256-channel detector provides spectral images of the ultraviolet auroral emissions in Jupiter's polar ionosphere.
Radio & Plasma Wave Sensor	Waves	Measures spectral energy distribution of radio and plasma waves in auroral regions.

***Fran Bagenal** is a planetary researcher at the University of Colorado, Boulder, and co-chairs Juno's Magnetospheric Working Group. She thanks Sushil K. Atreya (University of Michigan) for assistance with this article. For more information about Juno and its mission, visit **missionjuno.swri.edu** and **nasa.gov/mission_pages/juno**.*

The Mystery of Fast Radio Bursts



CSIRO

A decade ago astronomers discovered an ultrabright, ultrabrief flash of radio waves. Now, more than a dozen have been spotted, revealing tantalizing clues to their nature.

SHANNON HALL

On the night of August 24, 2001, a powerful blast of radio waves washed over Earth. By mere chance, the 64-meter radio dish at Parkes Observatory in New South Wales, Australia, happened to be pointed in the right direction and scooped up the signal. Although the burst appeared more than 100 times brighter than ambient noise — at levels that saturated the observing system — it vanished after just 5 milliseconds. Astronomers didn't even notice the all-too-brief event.

That is, until years later. In 2006 David Narkevic (then an undergraduate at West Virginia University) was wading through 480 hours' worth of archived Parkes data when he stumbled upon the brilliant pulse. And it wasn't just bright. It was also smeared over a wide range of radio frequencies, with lower-frequency waves noticeably delayed, a signature that implied the radio waves had traveled some 3 billion light-years to Earth.

If that was really the case, then only something extreme — radiating as much energy in a few milliseconds as the Sun emits in thousands of years — could have sparked such a powerful signal. "We made the bold claim based on one object that it was the prototype of a new population," says Duncan Lorimer, Narkevic's advisor.

Now, 15 years after the first radio flash, astronomers have discovered more than a dozen so-called *fast radio bursts* (FRBs), and they suspect a new one arrives at Earth every 15 seconds. But for many years, the idea of brilliant radio flashes from mysterious and faraway sources fueled controversy.

A Brilliant Flash, Then Nothing

After that first, bright burst, astronomers expected to see fainter examples, but years went by with no other finds. Matthew Bailes (Swinburne University of Technology, Australia), who was also on the discovery team, had a nagging concern that the burst might not have been astrophysical at all.

"I remember I actually had trouble sleeping," he says. "It was a little bit worrying, because I couldn't imagine how you could have something so far away and yet not see other examples of it that were a lot fainter but still above our detection threshold.

"The Lorimer burst, as it came to be known, almost seemed too good to be true," Bailes adds.

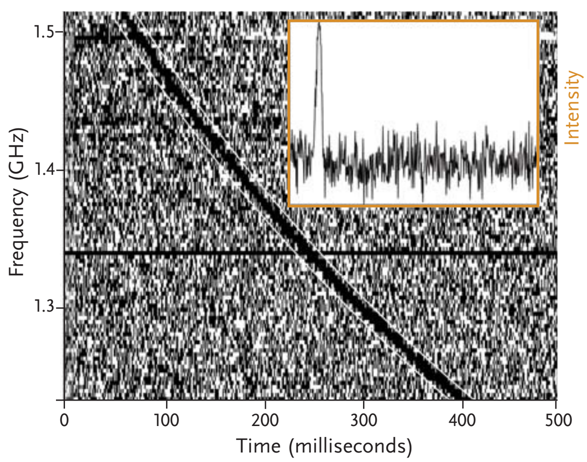
Then in 2011, a series of wacky bursts threw astronomers into further confusion. Sarah Burke-Spolaor (then at Swinburne University of Technology and CSIRO's Australia Telescope National Facility) and team searched through archival data and found 16 radio bursts they dubbed *perytons*. Like the Lorimer burst, these brief pulses of radio waves smeared across frequencies, initially indicating faraway sources. But unlike the Lorimer burst, the perytons shone brightly in 13 adjacent fields — a telltale sign that the signals were more likely of terrestrial (and probably manmade) origin.

"The original burst was marred with suspicion," Lorimer recalls. Although the peryton events didn't look exactly like the Lorimer burst, they were similar enough to cast doubt. Even members of the discovery team, including Bailes, turned a skeptical eye toward the first event.

Lorimer's faith that the event was truly astrophysical never faltered, but his proposals to search for more bursts were rejected year after year. "I was trying to get tenure back then and . . . I also needed a contingency plan," Lorimer says. While he admits that the daredevil in him would have loved to pursue FRBs full-time, he went back to his previous research to guarantee productivity. The buzz surrounding the Lorimer burst grew quiet.

But slowly, the tides began to turn. In 2013, seven years after the Lorimer burst was discovered, graduate student Dan Thornton (then at University of Manchester) was tasked with poring once again through Parkes' archives — and to everyone's surprise, four faint FRBs popped up. Then, Laura Spitler (Max Planck Institute for Radio Astronomy, Germany) and colleagues found one in real-time with the Arecibo Observatory in Puerto Rico. Kiyoshi Masui (University of British Columbia, Canada) and colleagues caught another one with the Robert C. Byrd Green Bank Telescope in West Virginia.

The new discoveries eliminated most doubts. But astronomers really started to relax when they traced perytons, which curiously tended to cluster around lunchtime, to the microwave oven in the Parkes Observatory's kitchen. Despite the unfortunately similar dispersion, that



LORIMER BURST The first fast radio burst appeared as a bright flash of radio waves (inset), discovered in 2006. The pulse smeared across frequencies: higher-frequency radio waves arrived first, followed by their shorter-frequency cousins.

LORIMER ET AL. / *NATURE* 2007

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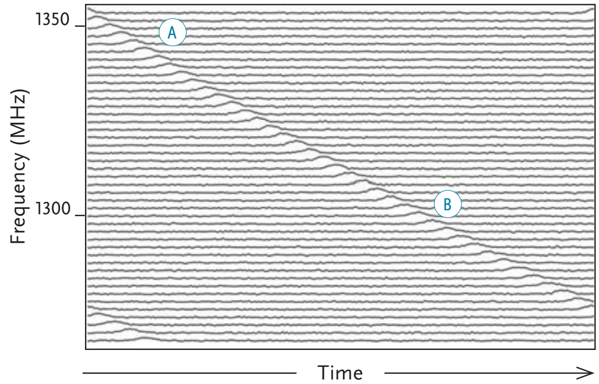


D. LORIMER & M. KRAMER

WIDE FIELD OF VIEW ***Left:*** **The Parkes radio telescope is equipped with a multibeam receiver (*inset*) that, like a CCD camera with multiple pixels, images 13 adjacent areas on the sky, each area 14 arcminutes across. Radiation from the Lorimer burst was detected in three of these areas, while the perytons were found in all 13 areas.** ***Right:*** **A classic "waterfall" plot shows the smear, or *dispersion*, of a pulsar's regular signal across frequency: its pulse appears first at higher frequencies (A), then at lower frequencies (B). Signals from both perytons and FRBs show similar dispersions.**

terrestrial source wasn't to blame for the Lorimer burst.

By early 2015 it became clear that FRBs were the latest astrophysical mystery waiting to unfold.

Flaring Stars Nearby, or Faraway Exotics?

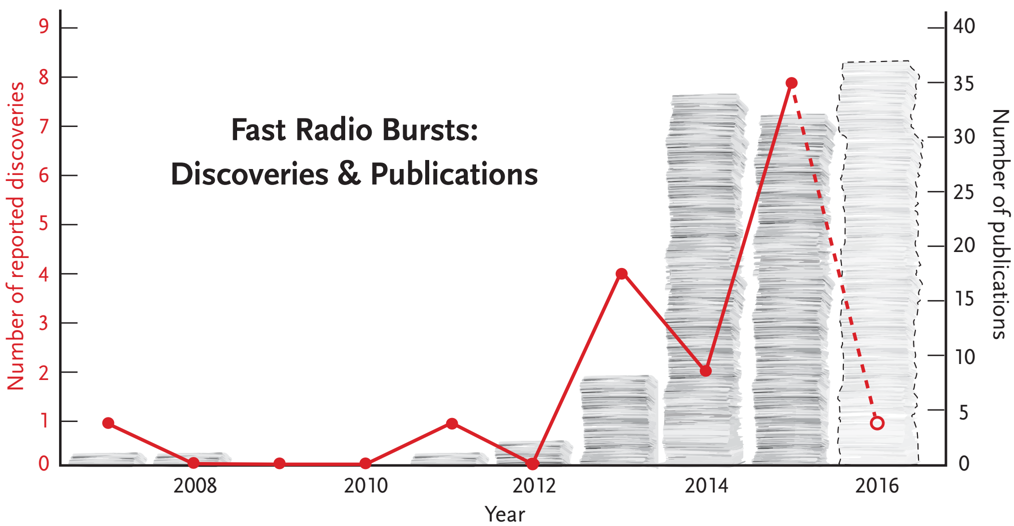
Before astronomers could determine just what might spark such a short and violent burst, they had to determine where these bursts originated. If they called the Milky Way home, they might be run-of-the-mill sources. But if their light crossed vast cosmological distances, then they would require unknown phenomena, perhaps pushing the boundaries of physics.

The answer lay in the Lorimer burst's smeared appearance in frequency and time: its higher-frequency radio waves arrived roughly 300 milliseconds before their lower-frequency cousins. This so-called *dispersion* occurs when radio waves travel through clouds of plasma, such as those found between stars and between galaxies.

The speed of light may be a constant 300,000 kilometers per second (671 million mph) in a vacuum, but it's slightly slower in plasma. How slow depends on the light's frequency: lower-frequency photons interact more with free electrons, which slows their passage. By comparing the arrival of the same radio signal at low and high frequencies, astronomers can measure how many electrons lie between Earth and the source. Assuming those electrons are spread out randomly along our line of sight, a higher measure of dispersion means more electrons and therefore a more distant source.

Because the Lorimer burst and the following FRBs had dispersion measures that couldn't be explained by the electrons in our galaxy alone, most astronomers thought they had to originate at cosmological distances.

But Abraham Loeb (Harvard University and Harvard-Smithsonian Center for Astrophysics) wholeheartedly disagrees. Loeb argues that, while dispersion tells



A GROWING FIELD This graph plots the number of fast radio burst discoveries reported in a given year, as well as the number of FRB-related papers published that year. Though the first fast radio burst was spotted in 2007, it took several years before another was found. It wasn't until discoveries began to pile up that the field really took off. (The 2016 data cover January through March.)

S&T: LEAH TISCIONE; SOURCE: NASA ASTROPHYSICS DATA SYSTEM / PETROFF ET AL. / ARXIV 2016 astronomers the number of electrons along the line of sight, it doesn't tell them where those electrons are located. So what if most of the electrons are in thick clouds around the source itself?

At first, Loeb thought that FRBs could be flares emitted from stars within our own galaxy. These stars' thick coronas could pack electrons tightly enough to have the same effect on passing radio waves as billions of light-years of the mostly empty intergalactic medium.

But few agree with Loeb's initial speculation — and even Loeb admits he enjoys going against the grain. Burke-Spolaor says, "It's important to have the contrarian in the mix to make everyone double-think their statistics." Nevertheless, she and many others are convinced that FRBs are extragalactic.

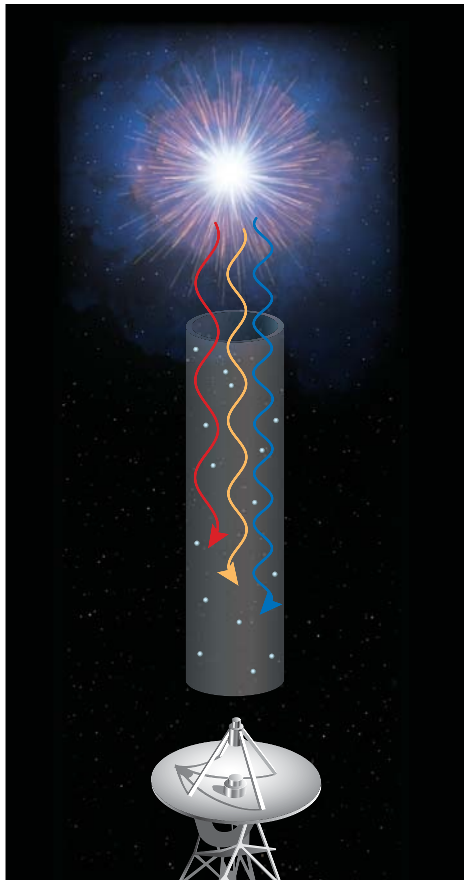
Here's why: although measuring dispersion can't tell astronomers exactly where the electrons are located, it can provide a pretty important clue. If those electrons are part of cold and sparse plasma, such as the stuff between stars, the delay decreases with frequency in a particular way (proportional to frequency squared). If, however, those electrons are part of the hotter and denser plasma found in a star's atmosphere, then the delay wouldn't follow that rule. But the smear of all FRB signals to date suggests that the pulses have mostly traveled through the sparser intergalactic medium.

The FRB detected at the Green Bank Telescope closed the distance debate. Not only did Masui and colleagues see that their FRB followed the dispersion measure expected for cold plasma, they also saw a subtle stretching out of the pulse's shape. This asymmetry implies the radio waves scattered off a thick envelope of plasma right after they were emitted. Whatever this envelope is, it's too big to support Loeb's idea of flare-prone stars — and it must lie in a distant galaxy.

Although Loeb agrees that his initial idea of flaring stars is out, he's still not sure these stars need to be cosmological. "The one thing to keep in mind . . . is that we should be agnostic," he maintains. "The mistake that many people make is they jump into conclusions when the data are very scarce."

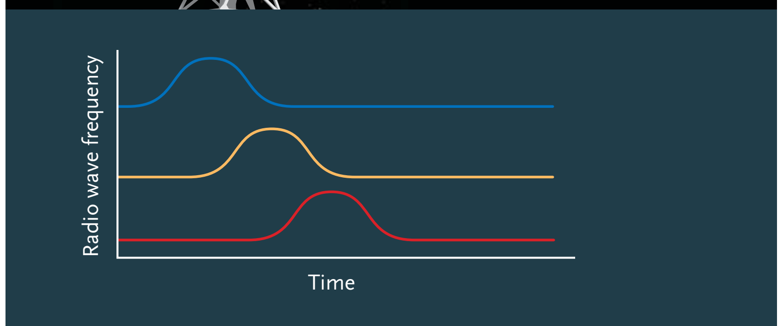
Placing FRBs on the Cosmic Map

To truly get a fix on an FRB's distance, astronomers need to pin it down to a host galaxy. It's a surprisingly hard task given that the Parkes receiver only sees details down to 14.4 arcminutes across — about half the angular size of the full Moon. Thousands of galaxies could fit in such a vast region. But if groups of radio telescopes working together could spot the burst, or its afterglow, they could narrow down where it came from. For example, the Australia Telescope Compact Array (ATCA), a collection of six 22-meter dishes, resolves regions as small as 1 arcsecond across. Astronomers could easily pinpoint a host galaxy within that smaller area on the sky.



DISPERSION MEASURE

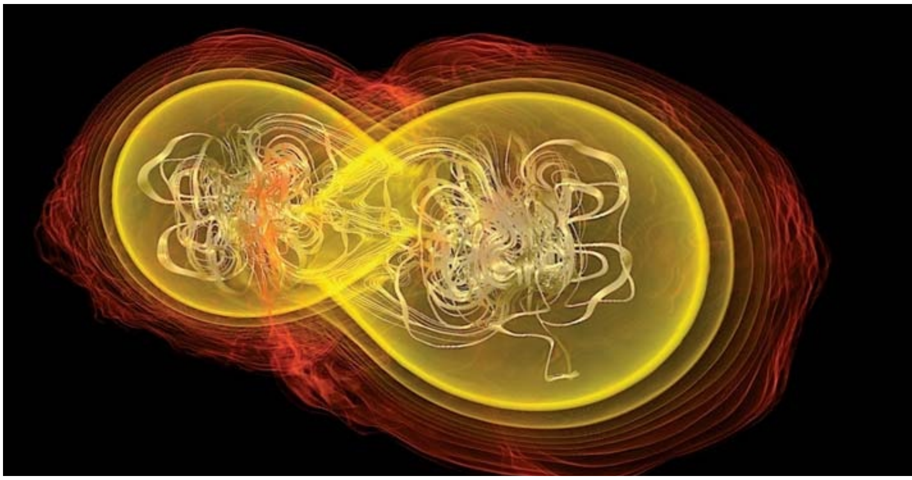
The speed of light may be a constant 300,000 kilometers per second in a vacuum, but space isn't quite as empty as it appears. When radio waves pass through sparse clouds of ionized gas, they slow down — the longer their wavelength and the more stuff they're passing through, the slower the radio waves go. Astronomers measure the delay in arrival times between different frequencies (the so-called *dispersion measure*) to tally up how much plasma the radio waves have traveled through and, by proxy, the distance to the source.



S&T: LEAH TISCIONE

AUSTRALIA TELESCOPE COMPACT ARRAY This collection of six 22-meter radio dishes resolves finer details than Parkes but covers a smaller area of the sky, so it's best suited to follow-up on FRB discoveries.

ALEX CHERNEY



COLLISION IMMINENT Simulations, such as the frame depicted here, show that inspiraling neutron stars merge their magnetic fields to create a single jet and a sudden clap of radiation. That makes inspiraling neutron stars one of the promising potential sources of FRBs.

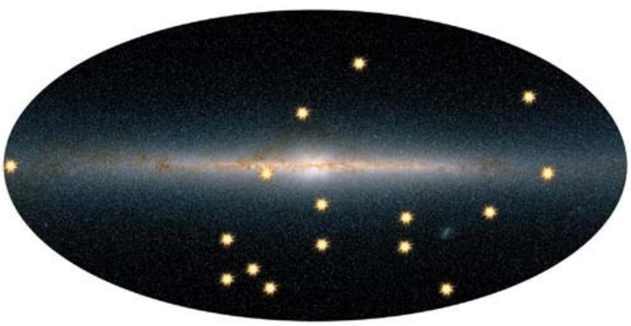
L. REZZOLLA (AEI) & M. KOPPITZ (AEI & ZUSE INSTITUTE BERLIN)

But first, astronomers need to catch an FRB in real time rather than in archived data — not an easy feat. In 2013 Parkes began sending all of its observations to "Green II," a supercomputer at Swinburne University of Technology. Within 30 seconds of a flash, the supercomputer pings 30 astronomers at 10 different institutions and alerts them to the burst's location so they can obtain follow-up observations.

The first several searches came up empty. But on April 18, 2015, the ATCA caught a slowly fading radio signal in an elliptical galaxy 5 billion light-years away. Initially, astronomers thought this signal was surely associated with an FRB that had occurred two hours earlier. If true, it would have proved that this FRB originated at a vast distance. It would even have hinted at a progenitor.

The study, however, was quickly disputed. Follow-up observations show the radio source is still there and has in fact brightened since the initial observations. It may be related to a supermassive black hole gobbling gas at the galaxy's center, but astronomers remain in limbo.

Nevertheless, with the field now poised to catch FRBs in action, and with the help of radio arrays that can image sources with much higher precision, it won't be long before astronomers pinpoint a source's location.



EXTRAGALACTIC EVIDENCE Plotting the 17 fast radio bursts known to date with respect to the plane of the Milky Way shows that the bursts can appear pretty much anywhere on the sky. Many researchers take FRBs' scattered distribution as a hint that these sources, whatever they are, lie far outside our galaxy.

S&T: LEAH TISCIONE; SOURCE: PETROFF ET AL. 2016; BACKGROUND IMAGE: 2MASS / J. CARPENTER, T. H. JARRETT, & R. HURT

When Theorists Come Out to Play

Even as astronomers continue to hunt for more definitive observations, they can still speculate about what creates FRBs. There are three solid clues: the bursts are brief, bright, and probably far away.

To astronomers, a brief signal points to a small source. In the case of a pulse only a millisecond long, the source must be small enough that a beam of light could cross it within that time — several hundred kilometers across, or roughly the length of Maine's coastline. And if these sources are placed at cosmological distances, they would have to be extremely powerful. What source that small could pack so much power?

Theorists' favorite answer is neutron stars. These crushed stellar corpses pack the mass of half a million Earths into a sphere only tens of kilometers across. And they offer plenty of opportunities that could produce the right energetics, Lorimer says: "comets crashing into neutron stars, neutron stars inspiraling, neutron stars collapsing into black holes." The list goes on.

The FRB Masui detected with the Green Bank Telescope might narrow the range of possibilities. That FRB's radio waves rotated in a corkscrew motion as they traveled through space. It's a signature caused by a powerful magnetic field, quite possibly originating from the source itself. So *magnetars* — neutron stars with powerful magnetic fields — might be the culprit, producing flares when starquakes break the magnetar's brittle crust. Alternatively, collapsing stars may generate jets of electrons that race along magnetic field lines.

A more exotic idea that Lorimer finds particularly tantalizing is *cosmic strings*: these large defects in the structure of spacetime could distort, releasing bursts of energy. He admits the idea is highly speculative. But "we should still keep an open mind and not just closet ourselves to thinking that it's a neutron star or the merger model of a collapsed black hole," he says.

Yet James Cordes (Cornell University) thinks just the opposite. "I wish they were something truly exotic," he says. "Everybody would like them to be really exotic: evaporating black holes, cosmic strings, something like that. But that's not what I would bet on at this stage."

The reason it's still a betting game is that, at least until very recently, every FRB was a one-hit wonder. If we didn't catch it the first time around, it was lost forever.

That all changed this year, when astronomers detected 10 additional outbursts from the FRB first detected with Arecibo. The repeated pulse ruled out cataclysmic scenarios, at least for this particular FRB. An evaporating black hole, for example, would never burst again.

Instead, Spitler, who led the team, is sticking to the neutron star theory. She thinks these pulses came from a pulsar — a neutron star that's spinning rapidly — like the one sitting in the Crab Nebula deep within the Milky Way. Although pulsars typically send out regular pulses of radiation, some (including the Crab pulsar) are known to occasionally give off much stronger bursts.

The trouble is, to be spotted from faraway galaxies the pulsar would have to flare so powerfully it would be unlike anything ever seen before. The team is on the lookout for additional pulses that would help narrow down the burst's location and distance — and its source.

In the meantime, at least Bailes can sleep at night again: he admits that the repeating source is the one that finally convinced him FRBs really are astrophysical.

X-RAY: NASA / CXC / ASU; HESTER ET AL.; OPTICAL: NASA / HST / ASU / J. HESTER ET AL.; RADIO: NRAO / AUI / NSF

CRAB PULSAR **Multiple wavelengths reveal the pulsar at the center of the Crab Nebula: X-rays (blue), optical (green), and radio (red). While this pulsar ticks as regularly as a clock, it also emits occasional giant bursts, a potential model for FRBs.**

Cosmological Probes Unlike Any Other

Regardless of their source, as long as FRBs are extremely distant, astronomers suspect that they have the potential to become unique cosmological probes — opening a new window on the universe.

That's because if observers can find an FRB's host galaxy, and correspondingly the source's distance, then its smeared-out radio waves can divine the density of the intergalactic medium. Cataloged in sufficient numbers, FRBs could be used to scan electron density across billions of light-years, a sort of MRI of the universe. FRBs in relatively nearby galaxies would allow astronomers to account for all of the universe's visible matter.

FRBs in more distant galaxies would enable astronomers to scan dark matter and dark energy. Astronomers typically compute a host galaxy's distance by its redshift, the redward shift light makes as it travels across the universe. But translating this straightforward measurement into distance can get a little messy: the calculation involves complex mathematical models that invoke dark matter and dark energy. By calculating distance in a second way, using the FRB's dispersion measure, astronomers can get a handle on these cosmological parameters.

Not that it'll be easy. Astronomers will need thousands of FRB detections before they can start grappling with cosmology. "When I first saw that and realized we needed 1,000, I thought 'you're dreaming,'" Bailes says. But, he adds, if history tells us anything, then it might only take a decade or two to catalog that many.

But it might not take that long. "The race is on in various parts of the world to try to get more of these things," says Simon Johnston (Commonwealth Scientific and Industrial Research Organization, Australia). He expects that a precursor to the Square Kilometer Array in South Africa will see several FRBs a day by mid-2016. And the Canadian Hydrogen Intensity Mapping Experiment (CHIME) might see a few dozen a day a year later.

What began as a single controversial discovery has now become a full-fledged field. Students' PhD projects are devoted to the topic, astronomers are organizing their first FRB-dedicated meeting, and new telescopes are coming online to aid the search.

As for Lorimer, he can start studying these bursts full- time — a luxury he didn't have 10 years ago. ✦

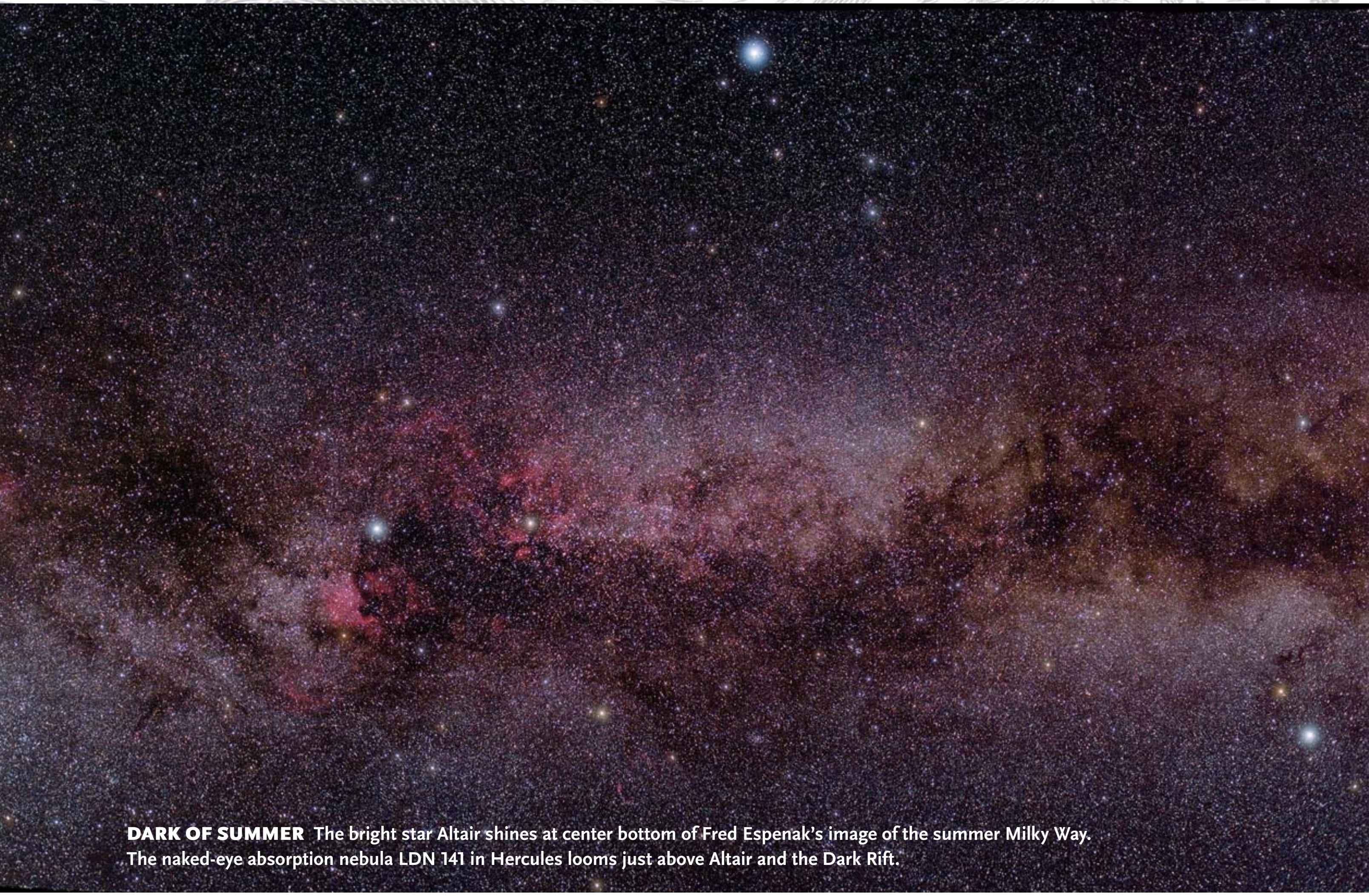
As a freelance science journalist, ***Shannon Hall*** *spends her days pondering the wonders of the universe from a local coffee shop.*

Cold, Dark, D

SPEND THE SUMMER WITH THE ABSORPTION NEBULAE OF **AQUILA**.

Richard P. Wilds

The central zone of the summer Milky Way shines with bright lights, including the 2nd-magnitude star Altair in the constellation Aquila, the Eagle. But this part of our galaxy is also notable for its dark features, namely, the Dark Rift, a band of cold molecular dust clouds that cuts down the middle of the bright galactic road. This naked-eye structure, which extends from Cygnus and floods out to the southwest in Ophiuchus toward Hercules in the west, offers observing targets ranging from naked-eye visibility to challenging deep-sky objects.



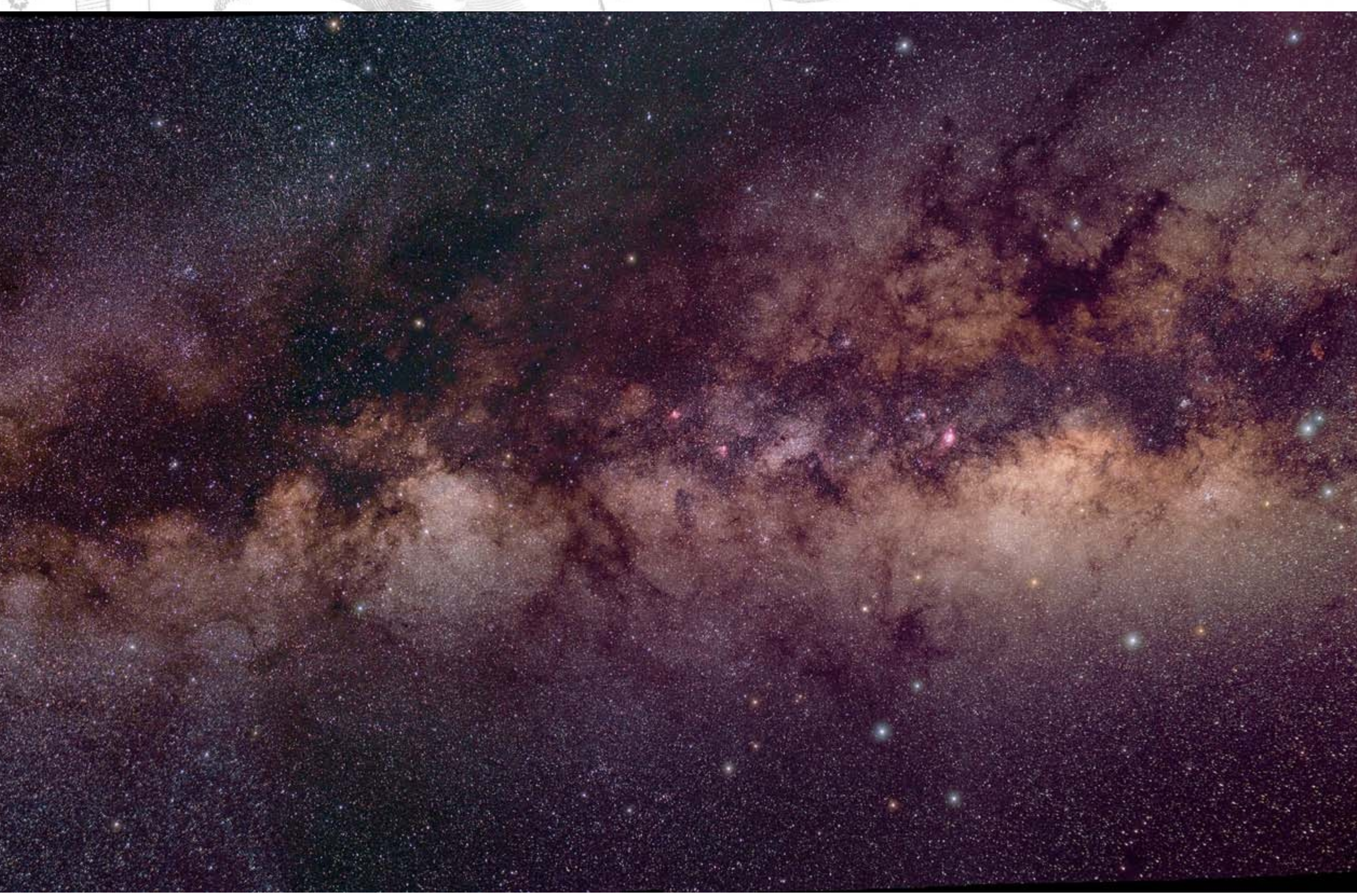
DARK OF SUMMER The bright star Altair shines at center bottom of Fred Espenak's image of the summer Milky Way. The naked-eye absorption nebula LDN 141 in Hercules looms just above Altair and the Dark Rift.

eep

Particularly engaging — particularly mysterious — are the dark, or absorption, nebulae spread throughout the region. Backlit by the bright suns of the Milky Way, these clouds appear as great absences of light, their dust particles too densely packed for visible light to penetrate.

Dark Discovery

Work to classify dark nebulae is ongoing, but the earliest effort came from the American astronomer E. E. Barnard, who, supported by the Carnegie Institution of Washington, published *An Atlas of Selected Regions of the Milky Way* in 1927 (**http://is.gd/EEBarnard**). An extension of Barnard's 1919 *Astrophysical Journal* paper "On the Dark Markings of the Sky, with a Catalogue of 182 Such Objects," the deep-sky atlas features reprints of the plates taken by Barnard with the 10-inch Bruce Photographic Telescope while in residence at Mount Wilson. Published posthumously, Barnard's enhanced list includes 349 dark objects.



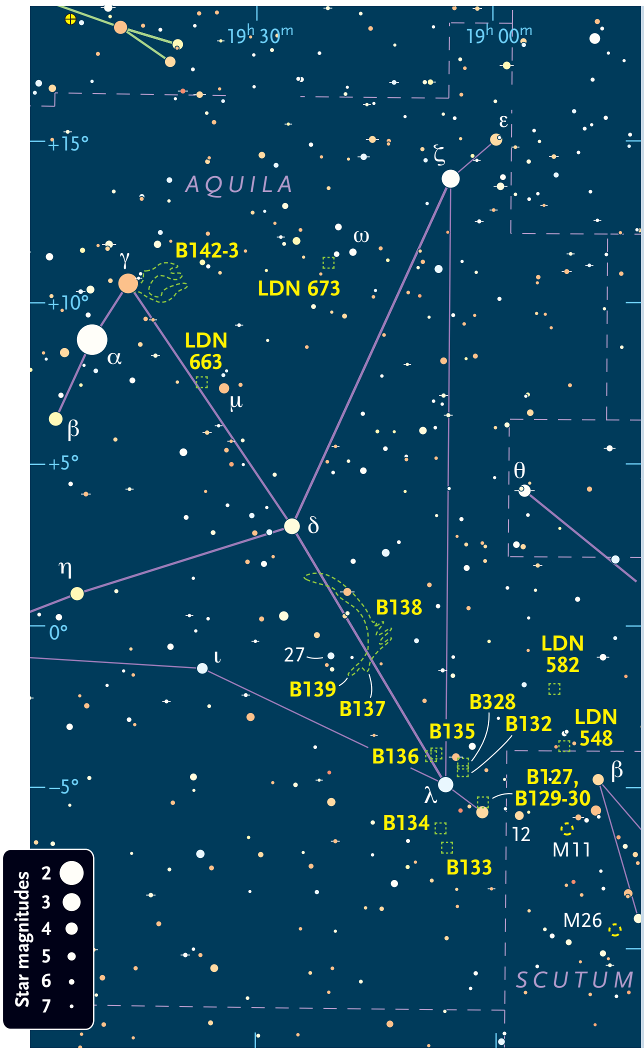
In 1962, Beverly Turner Lynds significantly extended Barnard's work, making a close examination of the red and blue plates from the National Geographic–Palomar Observatory Sky Atlas (POSS I). Lynds analyzed plates for the 879 fields covered by the sky survey, outlined the regions of dark nebulosity, calculated the position for the center of each cloud, and made visual estimates of the opacity of each cloud, on a scale of 1 (least opaque) to 6 (most opaque). The Lynds Dark Nebulae catalog included 1,802 objects, including Barnard's finds.

The Dark Bird of Prey

While dark nebulae are numerous throughout the Dark Rift region, let's start our night's journey in Aquila. Moving across the Eagle's wingspan, from west to east, we cross over the Great Rift to arrive at a pair of dark nebulae considered exemplary of their class. Just 1° west of Gamma (γ) Aquilae (Tarazed), we'll find **Barnard 142** and **Barnard 143**. Together, B142 and B143 form Barnard's E, a dark glyph etched on a starry background. These are two of the easiest dark nebulae to spot, well within reach of 10×50 binoculars. If you're new to this dark hunt, they make good training targets (*S&T:* Sept. 2014, p. 45).

Follow Aquila's spine down (southwest) to the bird's tail, where you'll find a number of defined dark nebulae, including **B127**, **B129**, and **B130**, all just north of the 4th-magnitude star 12 Aquilae. A row of three 7th- to 8th-magnitude stars arcs between 12 Aql and Lambda (λ), pointing to the noticeably red carbon star V Aql to the southeast and B130 to the northwest. Look for the "empty space" forming a rough L in the speckled star field — you may find it just a bit easier to spot B127 than its neighbors.

B132 and **B328** lie northeast of these inky pools. B132 forms an uneven, extended line; it might require more aperture to see. Look for its spikiness ½° northwest of 15 Aql. B328 is truly a small dark spot — very opaque, but only 4′ across. **B135** and **B136** float 40′ and 58′ east of 15 Aql, respectively; they're easier to distinguish, particularly B135, which stretches some 13′ across.



Dark Nebulae in Aquila

Object	Opacity	Size	RA	Dec.
B142	6	40.0′	$19^h\ 39.7^m$	+10° 31′
B143 (LDN 694)	6	30.0′	$19^h\ 41.4^m$	+11° 00′
B127 (LDN 544)	5	4.5′	$19^h\ 01.5^m$	–05° 26′
B129 (LDN 549)	5	5.0′	$19^h\ 02.1^m$	–05° 22′
B130 (LDN 542)	5	16.0′	$19^h\ 01.9^m$	–05° 36′
B132	6	8′ × 16′	$19^h\ 04.5^m$	–04° 25′
B328	6	4.0′	$19^h\ 04.8^m$	–04° 14′
B135	6	13.0′	$19^h\ 07.6^m$	–03° 55′
B136	6	8.0′	$19^h\ 08.8^m$	–04° 00′
B133 (LDN 531)	6	6.0′	$19^h\ 06.2^m$	–06° 54′
B134 (LDN 543)	6	6′ × 3.5′	$19^h\ 06.9^m$	–06° 14′
B139 (LDN 619)	5	11′ × 2′	$19^h\ 18.0^m$	–01° 27′
B137	3	2.5′ × 1′	$19^h\ 16.0^m$	–01° 19′
B138 (LDN 627)	2	140 × 140′	$19^h\ 14.0^m$	+00° 50′
LDN 548 (B113)	5	60.0′	$18^h\ 49.6^m$	–03° 42′
LDN 582 (B335)	5	30.0′	$18^h\ 52.6^m$	–01° 56′
LDN 663	6	6.0′	$19^h\ 36.9^m$	+07° 34′
LDN 673	6	10′ × 40′	$19^h\ 20.9^m$	+11° 15′
HH 32	—	1.0′	$19^h\ 20.5^m$	+11° 02′

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.

HUNTER WILSON

GHOSTLY GLYPH Together, B142 and B143 form "Barnard's E," an absorption nebula complex about ½° across, or roughly the same size as the full Moon.

AT THE EYEPIECE In addition to the arms and upper stem of the "E", Jeremy Perez captured additional points and webbed extensions through his 15×70 binos.

Recenter 12 Aql in your eyepiece, then move southeast about 1.5° to **B133** and **B134** (alternatively, drop 1.5° south of Lambda). Although the murky edges of the nebula may be hard to delineate, B133 is dense, boasting an opacity of 6. It should be detectable through 10×50 binoculars under good dark skies. B134 is a bit more challenging — consider 6 inches of aperture a reasonable starting point. As an added bonus: if you're upping the aperture, you can take a break to track down the magnitude-11.9 planetary nebula NGC 6751 just 23′ northwest of B134.

Moving several degrees to the northeast, well into the body of Aquila, locate the 5th-magnitude star 27 Aquilae. Using 27 Aql as your starting point, slide 5° 34′ to the southwest, in search of **B139**. A small planetary nebula, NGC 6778, shines 5° 30′ below this southeast-northwest dark smudge. Edge slightly northward and west to find the prominent dark notch of **B137**. From here, follow **B138** as it arcs up and across the Eagle's spine, curves behind 23 Aql, and ends near the stellar planetary nebula NGC 6790. The great crescent of this dark nebula stretches some 3°, the largest of the lines, curves, and dark spots we've examined so far.

Together, B137, 138, and 139 demonstrate the benefit of rich-field telescopes. If you find yourself fixating on these expansive swathes of darkness, consider investing in a scope that gives a wide field with low-power viewing. Orion and Explore Scientific, among other manufacturers, market rich-field refractors, but also consider reflectors with fairly fast focal ratios (around f/5). Otherwise,

ADAM BLOCK / MOUNT LEMMON SKYCENTER / UNIVERSITY OF ARIZONA

you're not going to be in a position to even know you have the object in view.

On the western side of Aquila, bordering the Dark Rift and the northeastern end of Serpens Cauda, you can find dark nebulae of great size, beginning with **Lynds Dark Nebula 548** (B113). LDN 548, representative of the large clouds in this region, is relatively easy to locate: it's on the north side of the Scutum Star Cloud, just ½° west of the stars 7 and 8 Aquilae and 8′ from the star HD 174323. Rated 5 in opacity, it shares the field with a much more difficult target, the bright nebula Sharpless 2-65.

Using the 7 and 8 Aql pair as a starting point, starhop approximately 1° 24′ north to find the southern edge of **LDN 582**. With a spread of 32′, this is a middle-sized object as far as dark nebulae go: not quite as far-reaching as B138, but significantly larger than B328.

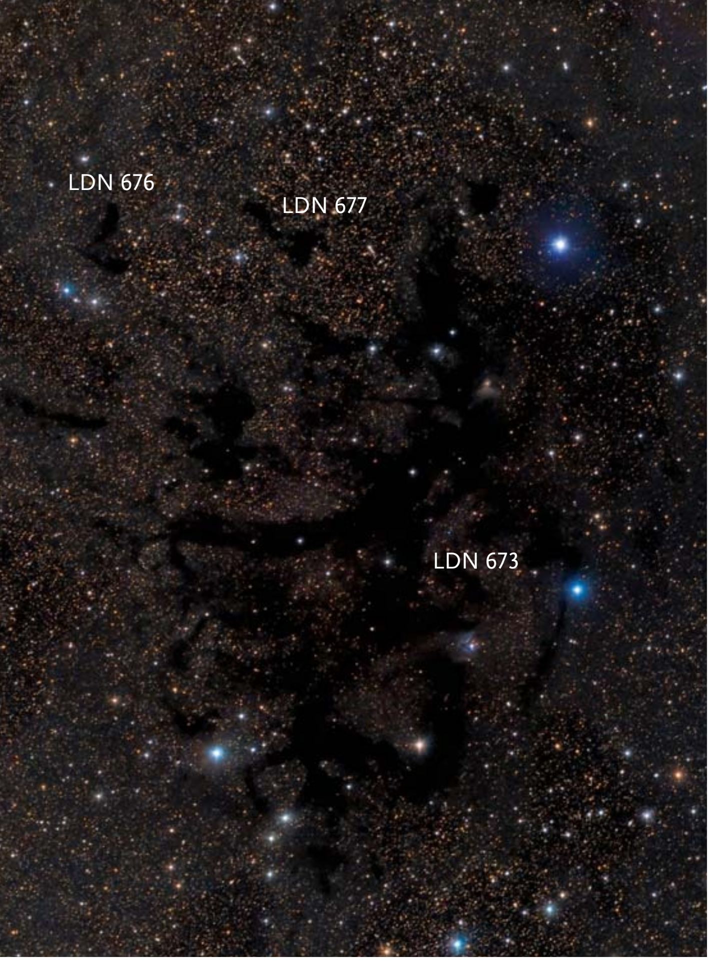
From here we can slew past several of the globular clusters in the area of western Aquila, including NGC 6749 and NGC 6760. In past centuries, astronomers often discussed globular clusters and dark nebulae together. For instance, William and Caroline Herschel, along with William's son, John Herschel, noticed these two types of objects appeared in the same region of the sky. They erroneously concluded that the dark areas were caused by stars being strangely gathered into the globular clusters, "as if the stars were collected from that place and had left a vacancy."

A fresh adventure awaits just off the Eagle's neck for those of you with large telescopes. **LDN 663** (B335) shows up particularly well in a dark sky with a great deal of aperture. From Mu (μ) Aquilae, move 40′ east to 7th-magnitude HD 184982. LDN 663 is directly east of this star and will appear as a very nice black drop of ink on your Milky Way.

Our last two objects float high in Aquila's western wing, in the central part of the Dark Rift that passes through the avian constellation. The dark nebula that stands out with little problem is **LDN 673**, its visibility muted only by the fact that it lies within the Dark Rift rather than in front of a bright Milky Way star cloud. Like the rest of the dark clouds in Aquila, LDN 673 is about 600 light-years distant. Its tendrils reach from a central pool of opacity, snaking and dissipating into dark fragments. To find LDN 673, drop 27′ south from 6th-magnitude Omega^2 (ω^2) Aquilae to 8th-magnitude HD 181384, then nudge gently east.

Our final target is, strangely enough, bright — a glowing nebulosity associated with star formation and known as a Herbig-Haro object. HH objects are formed when shockwaves created by material ejected by a new

BEACON OF LIGHT **Herbig-Haro 32, a shock region created by star formation, glows within an envelope of dust and dark molecular clouds.**



JIM THOMMES

FRACTURES AND FISSURES To locate a dark nebula, search for an "absence of light" that marks the central part of the structure. From there, work to tease out the extensions and fragments at the nebula's edge.

star plow into surrounding nebulosity; the interaction causes the light of hydrogen atoms and sulfur ions to glow. Nearly adjacent to LDN 673, **HH 32** is one of the easiest HH objects to capture. Slew just 10′ southeast of HD 181384 to find it. There are several 11th-magnitude and fainter stars in close proximity, and all are involved in some faint nebulosity, but HH 32 can be seen as a "finger extension" to the south of the 11th-magnitude variable star V1352 Aquilae. Their proximity gives the appearance of a double star that requires higher magnifications than I usually apply around dark nebula regions. The excitement for me is knowing that I'm looking at a relatively close dark nebula and seeing in it evidence of newly forming protostellar planetary systems much like our own solar system (only much younger, of course).

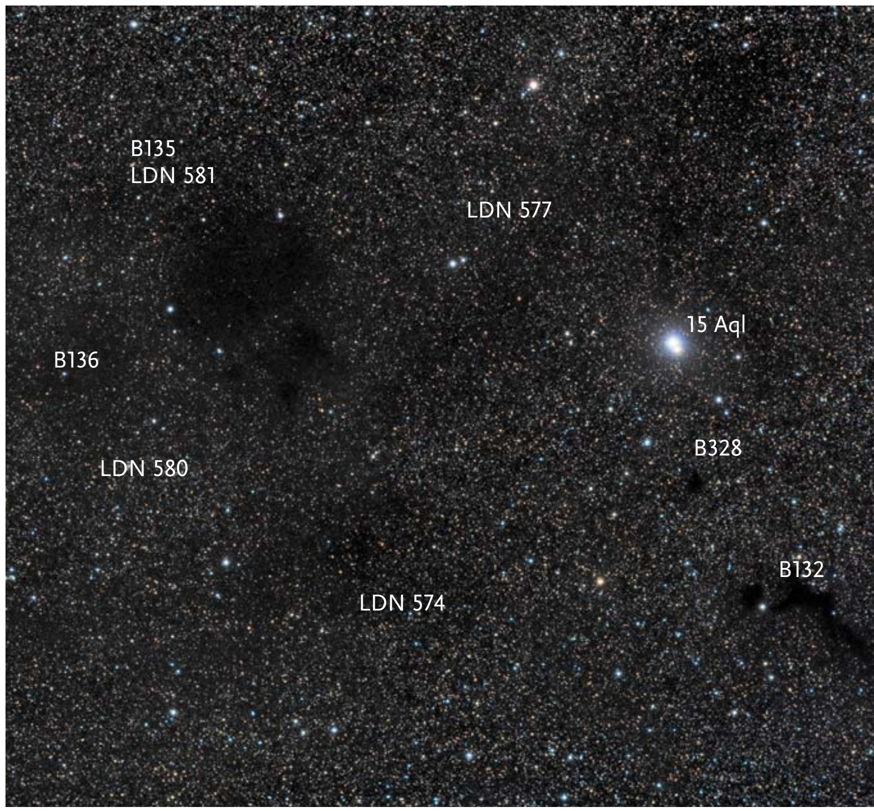
What to Use and When to Use It

Be aware that dark nebulae can be seen with many different telescopes — as long as the observer is willing to travel to an extremely dark location. For the most part, suburbia will not work. Dark nebulae are visible because they front brighter, more distant objects. In the case of those in Aquila, the "brighter, more distant objects" are provided by the star clouds of the Milky Way, and your ability to see them depends on how well your instruments handle the faint stars of these clouds.

While some dark objects — such as Barnard's E and B133 — are within binocular range, a basic beginning demands that your telescope be able to pull in 13th- to 15th-magnitude or fainter stars in relatively large fields of view. The 13th-magnitude limit is provided by telescopes with single-digit inches of aperture. Besides my trusty 2-inch f/8 refractor, I've also used a homemade 6-inch f/6 reflector and an Orion 120-mm (4.72-inch) f/5 refractor. The 15th-magnitude limit will generally require instruments with inches of aperture in the double digit range. I've used a 12-inch f/5 reflector and a 20-inch f/5 reflector, as well as various professional instruments of larger sizes, with great success.

Let me know your impressions of these wonderful and mysterious dark objects. From which dark sites and with which scopes were you able to observe them? Enjoy the view of the dark side of the summer Milky Way! ✦

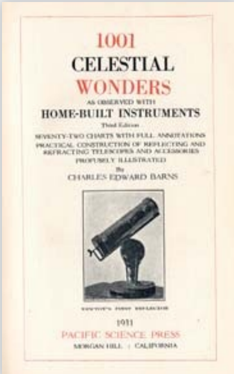
***Richard P. Wilds** is a member of the American Astronomical Society, Division for Planetary Sciences. His latest publication is* Bright and Dark Nebulae: A Pocket Field Guide (Springer, 2016). *Richard can be reached at **astromaster@att.net**.*



DAN CROWSON

GLOOMY GATHERING This LRGB image, processed from data gathered during a 240-minute total exposure with a 90-mm f/6.7 apochromatic refractor and imaging CCD reveals the dark objects in the vicinity of 15 Aquilae.

A Forgotten Observing Classic



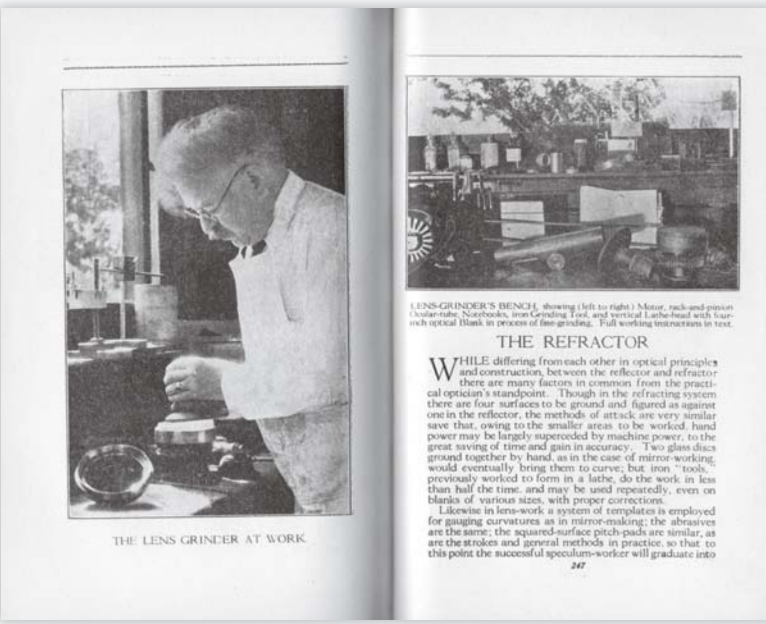
1001 Celestial Wonders, by C. E. Barns, deserves a place among the great observing guides of the last two centuries.

JAMES MULLANEY

Admiral William Henry Smyth. Rev. T.W. Webb. William Tyler Olcott. Robert Burnham, Jr. Nearly everyone who's loved astronomy in the last 170 years has revered at least one of those four names. They are the authors, in chronological order, of the classic guidebooks to the telescope-user's sky that dominated amateur astronomy since 1844.

At least, that's the abiding legend in the observing world today.

But another name should appear on this distinguished roster: Charles Edward Barns. You may never have heard of him, nor his charming and long out-of-print work from a lifetime ago: *1001 Celestial Wonders as Observed with Home-Built Instruments*. First published in 1927, with second and third editions in 1929 and 1931, this all-encompassing guide was, and is still, a treasure-trove of information and inspiration for stargazers.



DENNIS DI CICCO (2)

C. E. BARNS (1862–1937). Photographs of Barns are scarce, but he included this one in his all-encompassing astronomy guidebook.

Barns was a renaissance man in the truest sense. A prolific newspaperman, magazine journalist, novelist, and short-story writer, he traveled widely in India, China, and Japan. He set himself up as a theater impresario in Philadelphia, then later moved with his family to California, where he bought and ran a 20-acre apricot and prune orchard. There he established his own printing press and observatory. Like Robert Burnham, Jr., two generations later, he typeset and printed his astronomy compendium himself, by hand. He called his printing operation "Pacific Science Press." He dedicated *1001 Celestial Wonders* to his grandson, bubbling that astronomy is a "thrilling adventure" for youth, an "engrossing problem" for adults, and "a joy always" in old age. The book was widely hailed as soon as it appeared, and the first printing quickly sold out.

Barns tried to jam everything that stargazers of the time would need into one volume of, by its third edition, 328 pages. He provides instructions for making a Newtonian reflector (including how to silver the mirrors) and an achromatic refractor. He includes a picture of his own superb, homemade 10-inch f/9 reflector as an example of the former and a 93-mm refractor for the latter. He also gives instructions for making eyepieces, a prism star diagonal, a Herschel wedge, and a direct-vision spectroscope. He covers mountings, clock drives, astrophotography, observatory structures, and sundials. Peppered throughout the book are quotations from astronomers and philosophers and mini-essays on the astronomy of the day. The extensive booklist contains some truly interesting forgotten titles.

Barns also included 72 star charts drawn by himself. They plot deep-sky objects among the brighter naked-eye stars from the north pole to declination –10°, and where lower areas of the sky are especially interesting, to –30°. He overlaid the charts with fine coordinate grids for plotting additional objects, printed in red to vanish under red light outdoors at night — an astronomy-book first.

But most of all, this was a guide to telescopic sightseeing. What makes Barns stand out, and the real fascination of this work for observers today, are his charmingly gorgeous descriptions of stars, double stars, and deep-sky objects. He also covers the solar system with sections on the Sun, Moon, the planets, comets, and meteors.

His exalted descriptions of what he saw in his scopes were what attracted me to *1001 Celestial Wonders* when I first saw a copy in the Allegheny Observatory library in Pittsburgh over half a century ago. In the box below are some examples, for objects currently in the evening sky, of why this book continues to fascinate me and others lucky enough to own a copy. Their warmth, charm, and excitement rarely make it into modern observing guides, except where Barns himself is quoted!

For deep-sky wonders beyond the Messier catalog, Barns used the old Herschel designations ("H" and "h" for discoveries by William and his son John Herschel, respectively), rather than their NGC numbers — even though these were introduced in 1888 and were well established by Barns' time. (I've added them.)

There are a few puzzles in some of Barns' descriptions. One striking example is that of H IV-1 (NGC 7009, the Saturn Nebula in Aquarius), which he calls "Prodigious! Elliptical, pale blue, said to resemble the planet Venus." I'm sorry, no way. Beta Scorpii is listed in one place as an unresolved spectroscopic binary and in another as an "Intense, colorful" double (it's actually both). The neat triple system Mu Boötis is described as "Double Double. One of the pre-eminent quadruple systems." Nope; what did Barns see here? And H V-50 (NGC 6229 in Hercules) is described as a "Planetary nebula. Sea-green in starry triangle." It's actually a tight globular cluster, as should have been evident in his 10-inch scope, which, he said, had superb definition.

As an example of the disrespect and neglect some of the early classic observing guides have suffered, my personal copy of *1001 Celestial Wonders* was rescued several years ago from a discard pile in a storage room at a well-known major planetarium. It was deemed too outdated to be kept in the library! It's still to be found in some libraries and rare or used book shops, and also, occasionally, from individual sellers online.

I have recommended to Dover Publications in New York, known for reprinting out-of-the-way science classics, that they reprint this one. Dover was responsible for issuing Burnham's masterpiece (which he originally self-published as loose three-ring-binder pages) in the three-volume set that the astronomy world knows it by today. Dover also reprinted my own self-published *Celestial Harvest: 300-Plus Showpieces of the Heavens for Telescope Viewing & Contemplation*. They're considering *1001 Celestial Wonders* as this is written. If you love the simple joy of stargazing, you simply must get a copy somehow, somewhere! ✦

An avid stargazer for more than 60 years and author of 10 books on observing, ***James Mullaney*** *is a Fellow of the Royal Astronomical Society of London.*

THE REFLECTOR

It is fortunate, in a way, that a reflecting telescope is cheaper from the standpoint of initial outlay, as well easier to construct, than a refractor. But while the point of economy is well taken, let there be no illusions concerning the production of a good glass—the only kind that will requite your labor and insure permanent satisfaction. Any one can produce a mirror; but the accomplishment of a speculum of fine figure and perfect definition is nothing short of a personal triumph. As Byron said of Italian—"the most beautiful and easiest of languages to learn, the most difficult to master." Be not satisfied, therefore, with half measures, short cuts and partial success. Nothing but your best will bring the reward that your labors entitle you to—riches beyond price.

Unless handicapped by difficulties in securing good glass or a suitable mounting for the larger sizes, anything smaller than an eight-inch speculum is rarely advisable, and a ten-inch is better still. Beyond that size difficulties in-

TEN-INCH HOME-BUILT REFLECTOR. Focal length, 90 in. Tube, 11" galvanized iron irrigation pipe. Axes, 1½" machine-threaded pipe. Four ball-bearings from discarded motor-cars. Circles on 8"x2" weighted pulley-wheels. Base, sunken box filled with stone and concrete. Ocular, Huyghenian, 1½" e. f., in rack-and-pinion cell. Definition brilliant. Total cost of materials, $26.80.

225

DENNIS DI CICCO

For more pictures and celestial descriptions from the book: skyandtelescope.com/barns

FROM *1001 CELESTIAL WONDERS*, SUMMER SKY

M 51 CVN: Transcendent 'Whirlpool Nebula' of Lord Rosse, resembling more an eternal question-mark — a supernal celestial enigma, which in very truth it is.

Epsilon BOO: Gold and blue test-star.

H I-70 VIR [NGC 5634]: Beautiful lacery of nebulous stars.

Iota SER: A stellar Golconda south.

Beta LIB: Pale emerald unit resembling Uranus.

H VI-19 LIB [NGC 5897]: A universe of remote suns.

M 19 OPH: A bewilderment of loose clusters, accentuated by encompassing black rayless space-deeps.

95 HER: Beryl-sardonyx.

M 14 OPH: Extended—like blown star-dust.

M 23 OPH: Blazing wilderness of starry jewels!

M 20 SGR: Famous Trifid. A dark-night revelation. . .

Alpha (Vega) LYR: Resembles an old-mine Brazilian brilliant of purest water intensified to infinity!

H VIII-72 SER [NGC 6633]: Superlative! Grand star-clouds following.

Theta SER: Imperial pair in regal setting!

M 17 (Horseshoe/Omega/Swan Nebula) SGR: Curiously arched....Interesting with low power, but with increased magnification an exquisite object.

M 22 SGR: Another Colossus.

H IV-51 SGR [NGC 6818]: Like a monster fish-eye.

▶ **GRAB-N-GO TO** iOptron introduces the AZ Mount Pro ($1,299), which incorporates its newest "level and go" alignment setup. Simply level the mount using the built-in level indicator, turn on the power, and the AZ Mount Pro does the rest. The mount can be controlled using iOptron's popular Go2Nova hand controller, with a robust database of more than 212,000 objects, and it also includes built-in WiFi, allowing you to connect to your smart device running ASCOM-compliant planetarium apps. The AZ Mount Pro comes with a stainless steel tripod with 3-point leveling adjustments. It can support a scope of up to 33 pounds plus the included 10-pound counterweight, and its 6-inch dual-dovetail saddle accepts any Vixen- or Losmandy-style dovetail mounting plate.

iOptron 6F Gill St., Woburn, MA 01801, 866-399-4587; ioptron.com

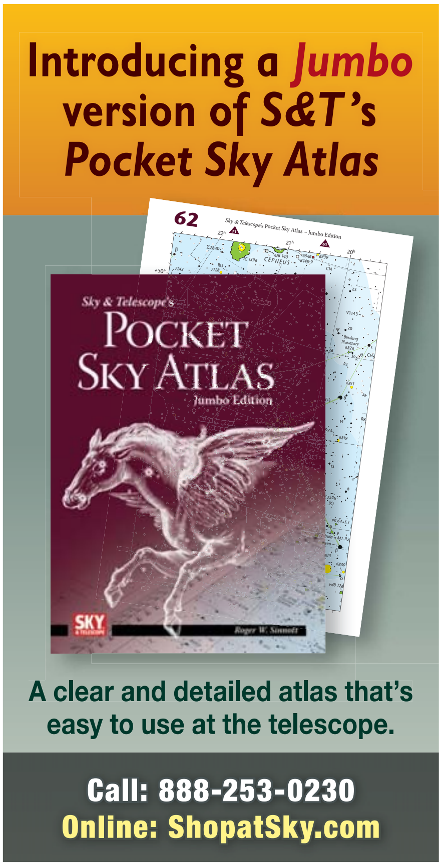
▲ **ALIGNMENT AID** QHYCCD rolls out the PoleMaster ($268), an electronic polar finderscope that helps you quickly and easily achieve near-perfect polar alignment. The PoleMaster is a small optic with an integrated camera that attaches in front of the polar finderscope on most equatorial mounts. Once installed, the unit produces an 11° × 8° field of view and its *PoleMaster* software then quickly identifies the star field and locates your mount's true polar axis — allowing you to adjust your alignment until you are within 30 arcseconds of the pole. PoleMaster can be calibrated to precisely match the true axis of your mount, and it connects to Windows PCs via a Mini USB cable. See the manufacturer's website for a list of compatible mounts.

QHYCCD Available in the U.S. from Astrofactors, 15922 Eldorado Pkwy., Suite 500, Frisco, TX 75035, 214-557-5979; astrofactors.com

HIGH-RESOLUTION CCD SBIG announces its newest entry in its STXL camera series, the STXL-16200 ($6,995). The camera features the newest Trusense detector, the KAF-16200, which packs a generous 16.2 million, 6-micron pixels in a 4,500 × 3,600 array measuring just 27 by 21.6 mm. The anti-blooming detector boasts a peak quantum efficiency of 56%, and the camera downloads a full frame in 13 seconds via a USB 2.0 or Ethernet interface to your PC computer. The STXL-16200 is capable of cooling down to 60°C below ambient temperature. Weighing 4½ pounds (2kg), the camera includes a 3-inch threaded accessory plate and is compatible with all current SBIG STXL accessories.

SBIG 59 Grenfell Crescent, Unit B, Ottawa, ON K2G 0G3, Canada, 613-225-2732; sbig.com

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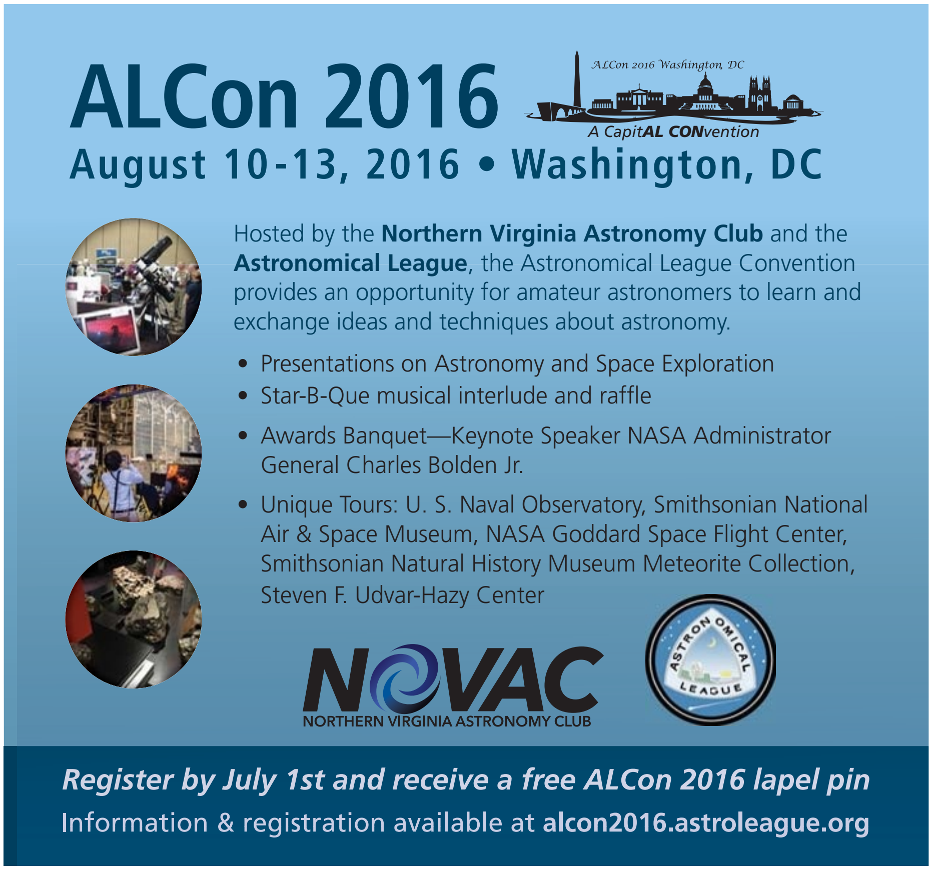
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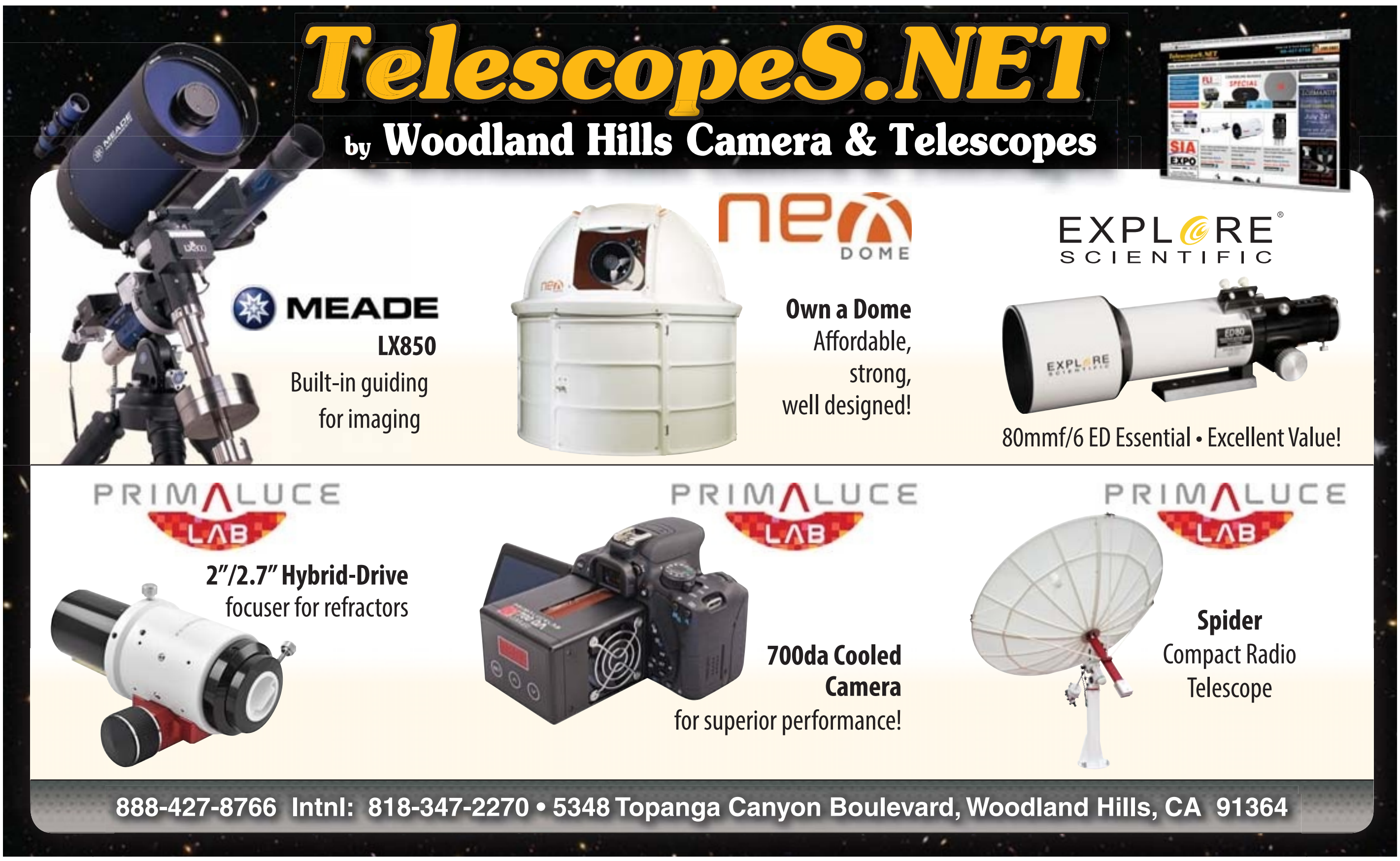
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In This Section

PHOTOGRAPH: JON RISTA

The dark, sinuous form of Barnard 72 snakes through the bright starfield of Ophiuchus (see page 58).

JULY 2016

2 **DAWN:** Aldebaran rises about 90 minutes before the Sun. As the orange giant climbs into morning twilight, look 3° or 4° to its lower left (seen from North America) for the thin waning crescent Moon. Binoculars will help.

4 Earth is at aphelion, farthest from the Sun for 2016 (94,512,904 miles).

7 **DUSK:** The waxing crescent Moon hangs low in the west, about 3° left or lower left of Regulus.

8 **DUSK:** Find the Moon about 4° lower right of bright Jupiter. The dimmer Sigma (σ) Leonis shines less than 1° above Jupiter.

11 **EVENING:** Look for the first-quarter Moon ornamenting the southwestern sky. In the deepening twilight, watch for the white light of Spica to appear some 5° to 6° below and left of the Moon.

15 **NIGHT:** The waxing gibbous Moon, Saturn, and Antares form a roughly vertical line in the south after the Sun sets. Watch the trio slowly wheel across the sky until they set around 3 a.m.

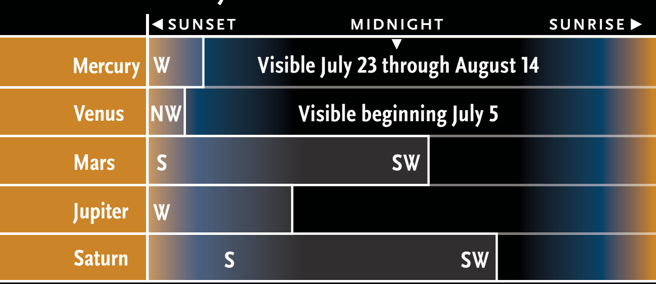
28 **MORNING:** The modest Delta Aquariid meteor shower peaks around this date. It's best for observers at southerly latitudes; see page 50.

29 **DAWN:** The waning crescent Moon occults Aldebaran for observers in much of eastern North America; see p. 51.

30 **DUSK:** As evening twilight deepens, look to the west-northwest, where Mercury shines ½° from fainter Regulus.

Planet Visibility

SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH



Moon Phases

New July 4 7:01 a.m. EDT
First Qtr July 11 8:52 p.m. EDT
Full July 19 6:56 p.m. EDT
Last Qtr July 26 7:00 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 / 31	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.

When

Late May	2 a.m.*
Early June	1 a.m.*
Late June	Midnight*
Early July	11 p.m.*
Late July	Dusk

* Daylight-saving time.

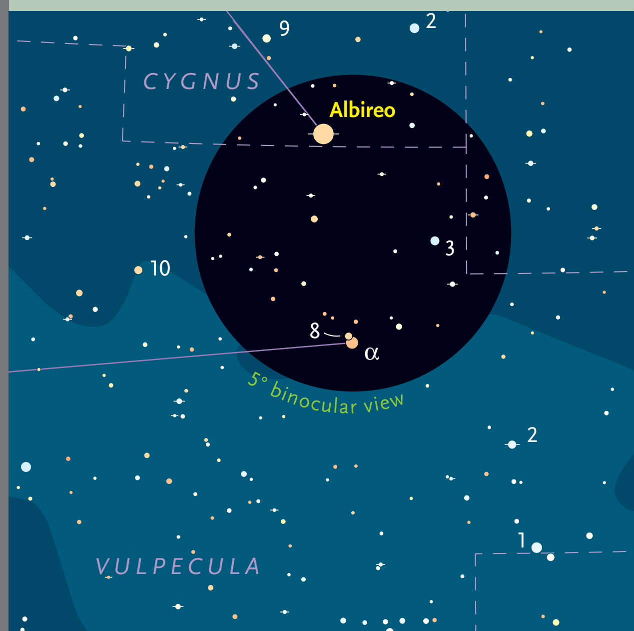
The False Albireo

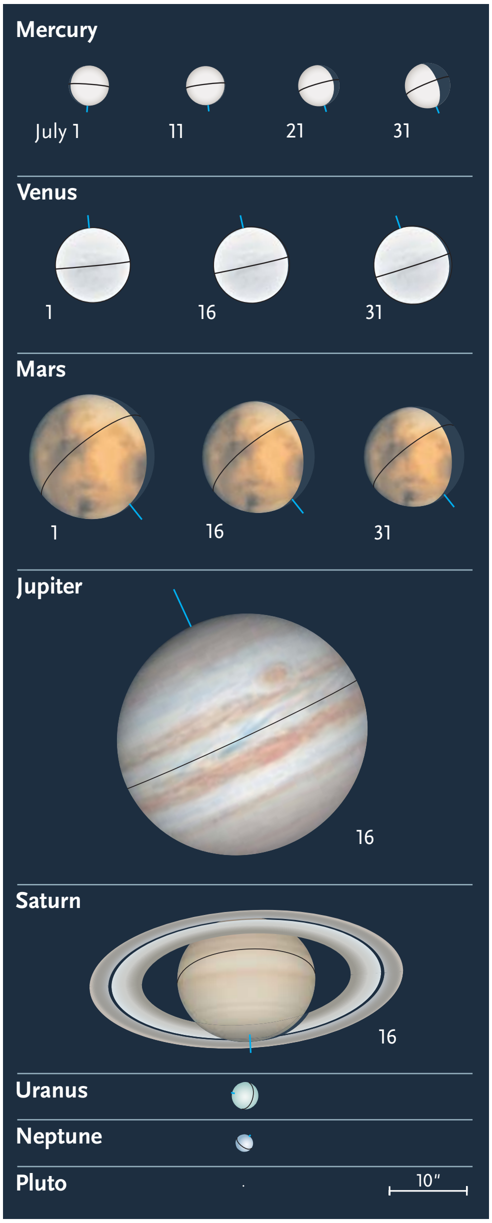
Are there particular celestial objects that have bedeviled you time and again? For a long time, **Alpha (α) Vulpeculae** was a thorn in my side. Along with **8 Vulpeculae**, Alpha forms a wide "optical" double star — not a true binary system, just two unrelated stars coincidentally aligned as seen from Earth. At 485 light-years from Earth, 8 Vul is much farther off than Alpha, which lies about 297 light-years away.

To my eyes, the two stars have always shown a strong color contrast, with Alpha a vivid orange and 8 Vul a soft blue. Of course, if one's looking for an orange and blue double star in this part of the sky, the go-to favorite is Albireo in the neighboring constellation Cygnus. And that was my problem — in my early years as a stargazer, I'd often go looking for Albireo and land on Alpha Vul instead. But Alpha and 8 Vul have a much wider separation than Albireo — about 7 arcminutes — and even the smallest binoculars will split them easily.

Here's the crazy thing: 8 Vul is a *K*-type giant, so it's intrinsically orange, not blue. But I've always seen it as blue, from the first time I stumbled across it (looking for Albireo, of course), to this morning's predawn observing run. Perception of color in doubles is notoriously variable from one observer to the next, and I can only assume that the deep reddish-orange of brighter Alpha makes 8 Vul look blue by comparison — at least to my eyes. I'm curious to hear what others make of this interesting pair.

Alpha has another felicitous property: it's almost halfway along an imaginary line from Albireo to Collinder 399, the asterism also known as Brocchi's Coathanger. So at least it's in good company! ✦



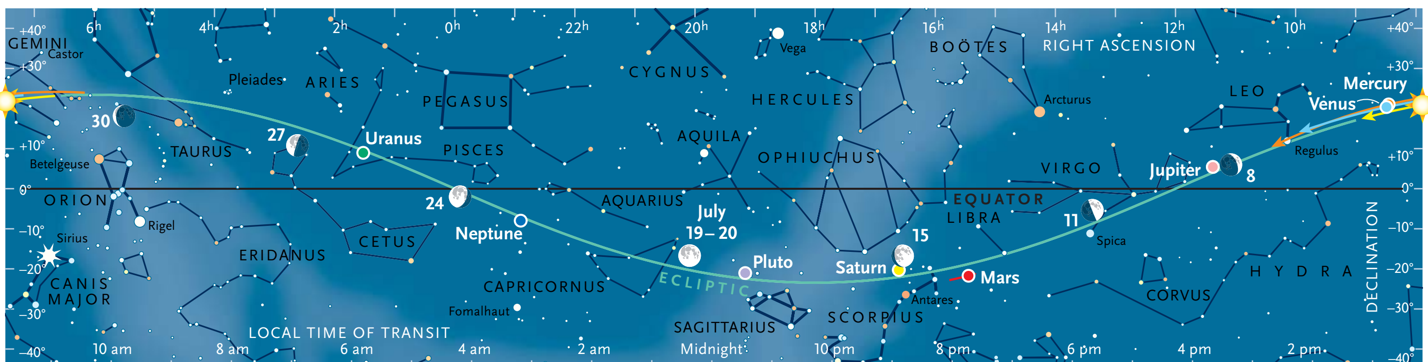


Sun and Planets, July 2016

	July	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$6^h\ 40.8^m$	+23° 06′	—	–26.8	31′ 28″	—	1.017
	31	$8^h\ 41.6^m$	+18° 16′	—	–26.8	31′ 31″	—	1.015
Mercury	1	$6^h\ 08.5^m$	+23° 57′	7° Mo	–1.6	5.2″	95%	1.287
	11	$7^h\ 42.6^m$	+23° 04′	5° Ev	–1.7	5.1″	98%	1.329
	21	$9^h\ 05.0^m$	+18° 26′	15° Ev	–0.7	5.3″	86%	1.261
	31	$10^h\ 10.0^m$	+12° 07′	22° Ev	–0.2	5.9″	73%	1.143
Venus	1	$7^h\ 09.8^m$	+23° 22′	7° Ev	–3.9	9.7″	99%	1.719
	11	$8^h\ 02.5^m$	+21° 39′	9° Ev	–3.9	9.8″	99%	1.702
	21	$8^h\ 53.6^m$	+18° 55′	12° Ev	–3.9	9.9″	98%	1.679
	31	$9^h\ 42.7^m$	+15° 18′	15° Ev	–3.9	10.1″	97%	1.651
Mars	1	$15^h\ 18.9^m$	–21° 01′	133° Ev	–1.4	16.3″	93%	0.573
	16	$15^h\ 25.7^m$	–21° 37′	121° Ev	–1.1	14.6″	90%	0.640
	31	$15^h\ 43.4^m$	–22° 41′	111° Ev	–0.8	13.1″	88%	0.717
Jupiter	1	$11^h\ 13.5^m$	+6° 18′	67° Ev	–1.9	34.3″	99%	5.751
	31	$11^h\ 31.2^m$	+4° 21′	44° Ev	–1.7	32.1″	100%	6.136
Saturn	1	$16^h\ 38.6^m$	–20° 21′	152° Ev	+0.2	18.2″	100%	9.126
	31	$16^h\ 33.2^m$	–20° 16′	122° Ev	+0.3	17.6″	100%	9.464
Uranus	16	$1^h\ 30.5^m$	+8° 49′	89° Mo	+5.8	3.5″	100%	19.940
Neptune	16	$22^h\ 53.2^m$	–8° 02′	132° Mo	+7.8	2.3″	100%	29.264
Pluto	16	$19^h\ 07.8^m$	–21° 09′	172° Ev	+14.1	0.1″	100%	32.130

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-July; 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

Sailing a Starry River

Take a journey down the summer Milky Way.

. . . It's dark and wide and deep
Towards the sea it creeps
I'm so glad I brought along my mandolin
To play the river hymn

You can ride on it or drink it
Poison it or damn it, fish in it and wash in it
Swim in it and you can die in it
Run, you river, run....

....If you hear a lonesome drone
That's as common as a stone
And gets louder as the day is growing dim
That's the river hymn

The whole congregation was standing
On the banks of the river
We are gathered here
To give a little thanks, thanks

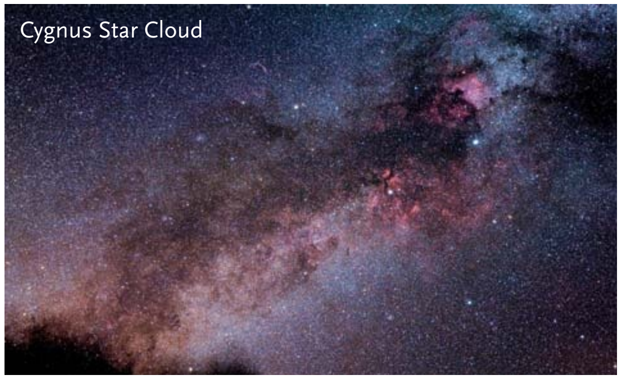
— Robbie Robertson, *The River Hymn*

We give thanks for the rivers of Earth — all the rivers on this water planet we call home. But we also should remember to give thanks for the river of the sky.

I'm not talking about the constellation Eridanus, the River, which meanders through the evening sky of late autumn and winter. For as wonderful as that constellation is, its marvels are enormously exceeded by those of what many cultures have seen as the Heavenly River. I'm referring, of course, to the luminous band of the Milky Way — and especially the Milky Way of summer nights.

Starting the voyage at Cygnus, the Swan. Where do we start our journey on the heavenly river? The lower parts of the Milky Way, especially the grand Sagittarius region, may be hidden from you by trees or buildings, or may often be veiled by summer haze, which is thicker lower in the sky. So the starting point for our ship voyage on the summer Milky Way will usually be the bright part that passes overhead as seen from mid-northern latitudes: the Cygnus Star Cloud.

By the year 2000, light pollution had worsened to the point where it prevented at least 20% of the world's population and more than 2/3 of the U.S. population from seeing the Milky Way. The Cygnus Star Cloud, however, can be seen overhead — just barely — even when the



EDDIE YIP / CC BY-SA 2.0

limiting magnitude is as poor as +5.0 or +4.8. So the Cygnus Star Cloud is a last trace of the Milky Way for many of us to hold onto and — hopefully for all of us — from which to begin the restoration of dark skies.

As deep-sky pioneer Walter Scott Houston once noted, under the very best conditions of sky darkness and transparent atmosphere, the glow of the Cygnus Star Cloud can break up into individual 7th-magnitude and even 8th-magnitude stars to the naked eye. But under common dark skies we actually see the bright stars of the Swan's pattern reduced in prominence by the Milky Way glow in which they are immersed. This may be a key reason why there are fewer myths connected with Cygnus itself than with many other constellations.

Sailing around even just Cygnus, even just with the naked eye, brings us to many delightful places. Can you ferret out the form of the North America Nebula from the surrounding Milky Way with your naked eye? Binoculars or finderscopes can sometimes show the brightest parts of the Veil Nebula.

The Great Rift of dark clouds of interstellar dust that splits a long section of the Milky Way begins in Cygnus, with the Northern Coalsack, southeast of Deneb. But the patch of darkness in Cygnus that first attracted me back in the 1970s was a deep sideways cut — a mighty indentation in the Milky Way located not far north-northeast of Deneb. It was only later I learned this narrowing of the Milky Way's flow is primarily caused by a huge dark cloud called Le Gentil 3.

Our voyage continues next month. In the next column, we'll continue our journey south through Scutum and Serpens and through comparisons of the Milky Way to two rivers of fantasy, the Anduin and the Yann. ✦

Full House

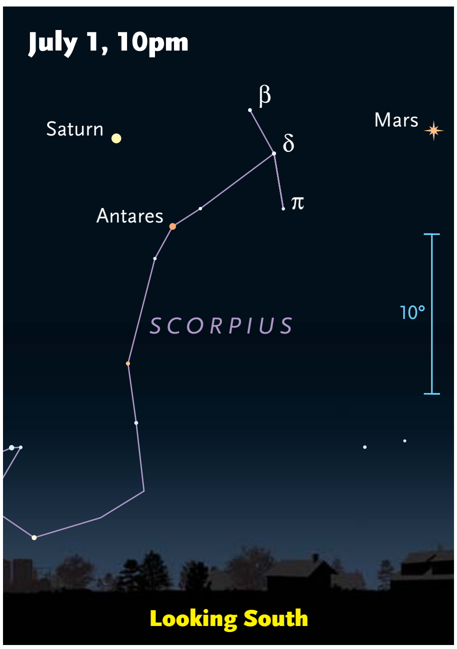
Every planet in the solar system makes an appearance this month.

Throughout July, Jupiter hangs in the west at dusk — lower with each passing week. In late July Mercury and Venus peek into view below it, presaging a gathering of the three planets in late August. Meanwhile, even though Mars is fading rapidly, it still shines brilliantly for the first half of the night, creeping back toward Saturn, Antares, and the head of Scorpius.

DUSK

Vibrant **Jupiter** beams in the west at dusk all month. Even at the start of July, however, the magnitude –1.9 world stands only about 30° high an hour after sunset — and it's much lower by month's end.

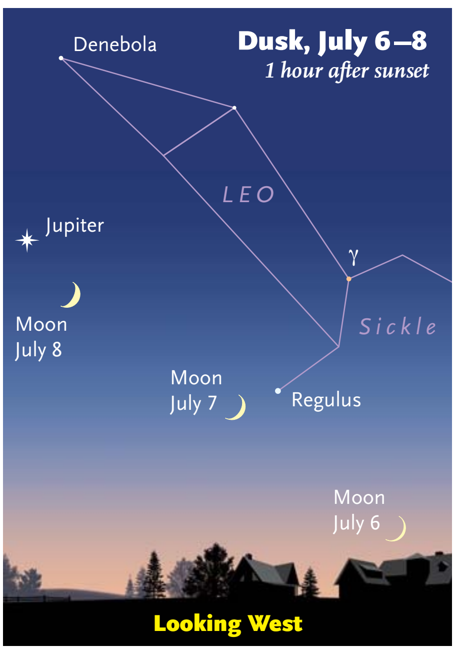
The interval between sunset and Jupiter-set shrinks from 3½ hours to less than 2 over the course of the month. To get a reasonably sharp telescopic view of clouds and bands on Jupiter's shrinking disk (now roughly 33″ wide), observe it as early in the evening and therefore as high as possible.



Jupiter creeps just ½° south of 4th-magnitude Sigma (σ) Leonis around July 12th and on eastward, nearly to the Leo-Virgo border, by month's end. Regulus shines increasingly far — some 20° — to Jupiter's lower right. Near month's end, two other eastward-moving planets, Venus and Mercury, approach the lion's forefoot on their way to catching Jupiter.

Venus reached superior conjunction behind the Sun on June 6th and **Mercury** does the same on July 6th. At the beginning of July, Venus sets only about half an hour after the Sun for viewers around latitude 40° North. First binocular or telescopic visibility of Venus and Mercury may be possible around mid-month, when the planetary pair set about 45 minutes after sunset. Look very low in the west-northwest soon after the Sun disappears on July 16th, when –1.1-magnitude Mercury gleams just ½° above much-brighter –3.9-magnitude Venus.

In the final week of July, Mercury, now about 5° upper left of Venus, moves closer to Regulus until the two are ½° apart on the American evening of July 30th. Optical aid will probably be needed to distinguish magnitude +1.4 Regulus from Mercury's small but brighter gibbous form, glowing at magnitude –0.2. Venus will pass Regulus on August 5th.



EVENING

Mars and **Saturn** are in the south-southwest at nightfall, two majestic planets in a majestic starscape that features Antares and the body of Scorpius.

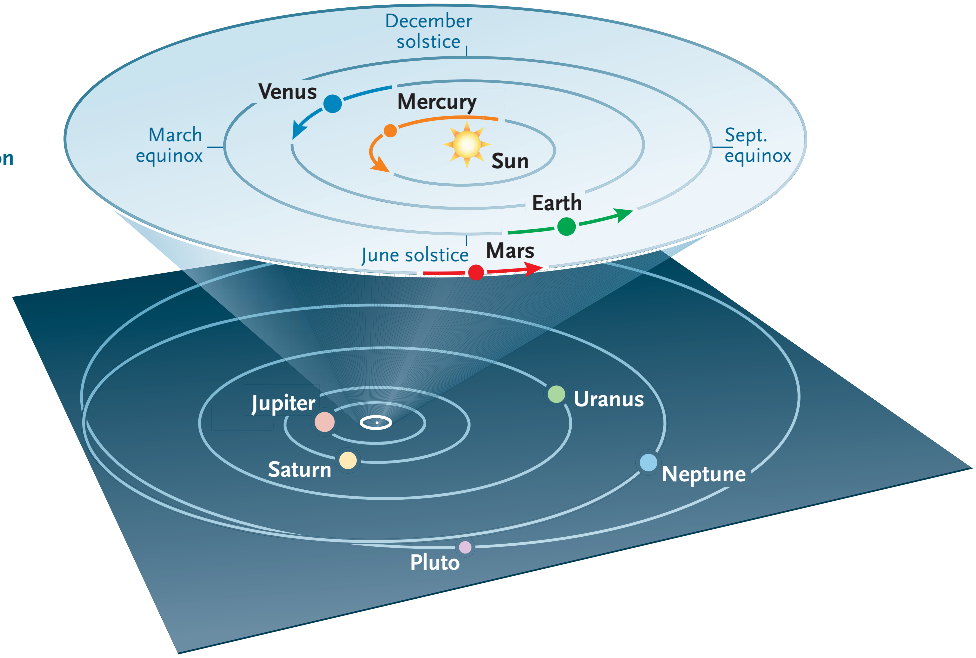
Mars halted retrograde (westward) motion in Libra on June 30th; it glides eastward almost to the bright head of the scorpion by the end of July. The Red Planet continues to fade, like a mighty but dying orange-gold ember, over the course of the month, dimming by almost half from magnitude –1.4 to –0.8. Its disk shrinks in telescopes from 16″ to 13″ wide during the month. Still, even at month's end, Mars outshines any visible stars, and on calm summer nights of good seeing may show considerable detail in medium-to-large telescopes.

Mars transits the meridian after 9:30 p.m. and sets around 2:20 a.m. on July 1st. By July 31st, the transit time has moved forward to a little before sunset, the setting time to before 1 a.m.

Saturn, having passed opposition on June 3rd, continues to shine 6° north of Antares in southern Ophiuchus. The Ringed Planet continues to retrograde throughout July, its westward motion narrowing the gap between it and eastward-moving Mars from 19° to 11°. At the same time Saturn dims a little, from magnitude +0.1 to +0.3. The apparent diameter of its globe decreases slightly, but the glorious rings continue to beckon us with an inclination of 26°, nearly their most open.

ORBITS OF THE PLANETS

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



Saturn crosses the meridian around 11 p.m. as July starts and before 9 p.m. as the month ends.

NIGHT

Pluto arrives at opposition on July 7th. It spends this season in the naked-eye Teaspoon asterism, northeast of the more famous Teapot of Sagittarius. A finder chart for this fascinating but dim (14th-magnitude) world appears on page 48.

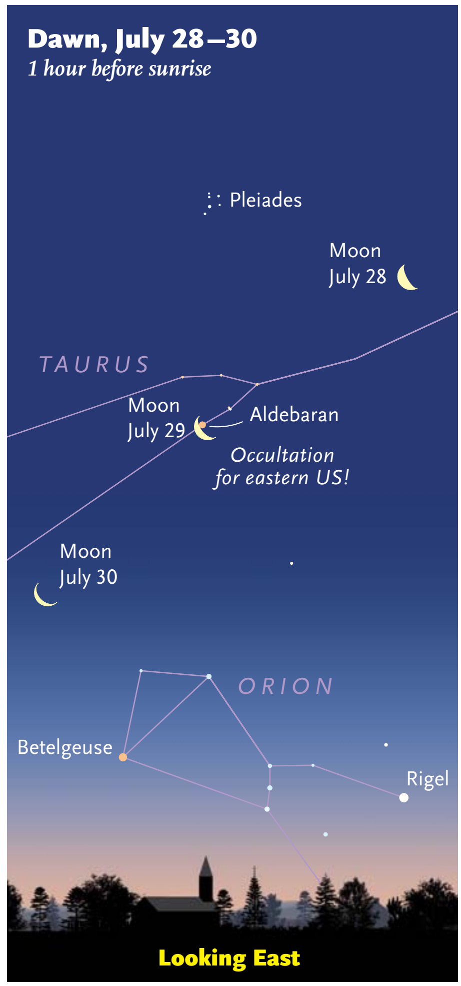
DAWN

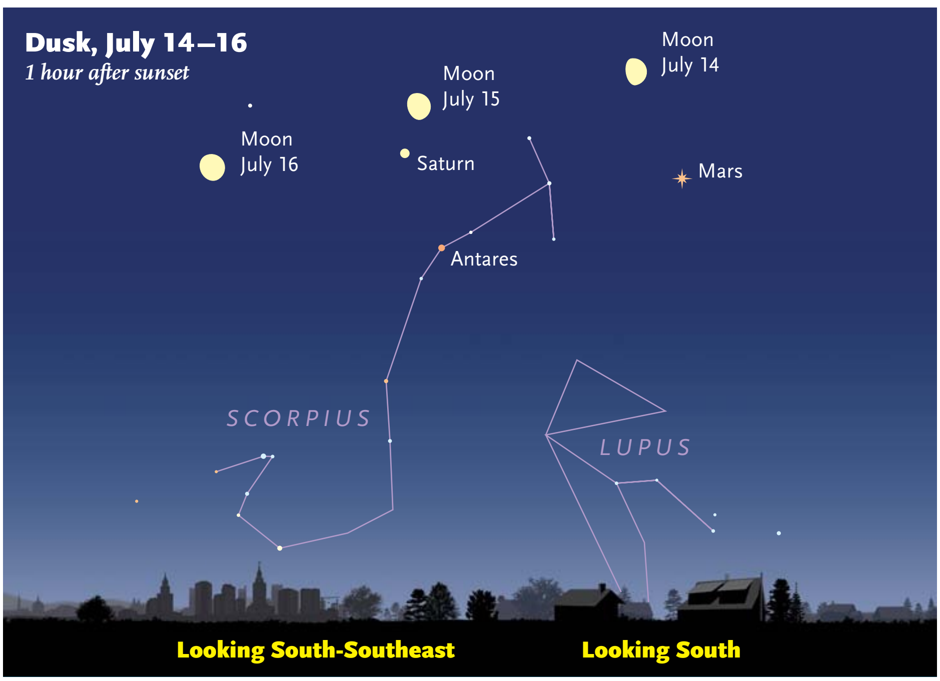
Neptune, in Aquarius, rises in the evening and reaches the meridian during morning twilight. **Uranus**, in Pisces, rises in late evening and is best seen just before the beginning of dawn.

EARTH AND MOON

Earth reaches aphelion, its farthest from the Sun for the year, around noon EDT on July 4th. Its distance from our star then is 94,512,904 miles, only 3% farther than at perihelion in January.

The **Moon**, waxing across the evening sky, shines below Jupiter on July 8th, Spica on the 11th, Mars on the 14th, and Saturn on the 15th. The waning lunar crescent occults Aldebaran for the southern United States and Central America on the morning of July 29th; see page 51 for details. ✦





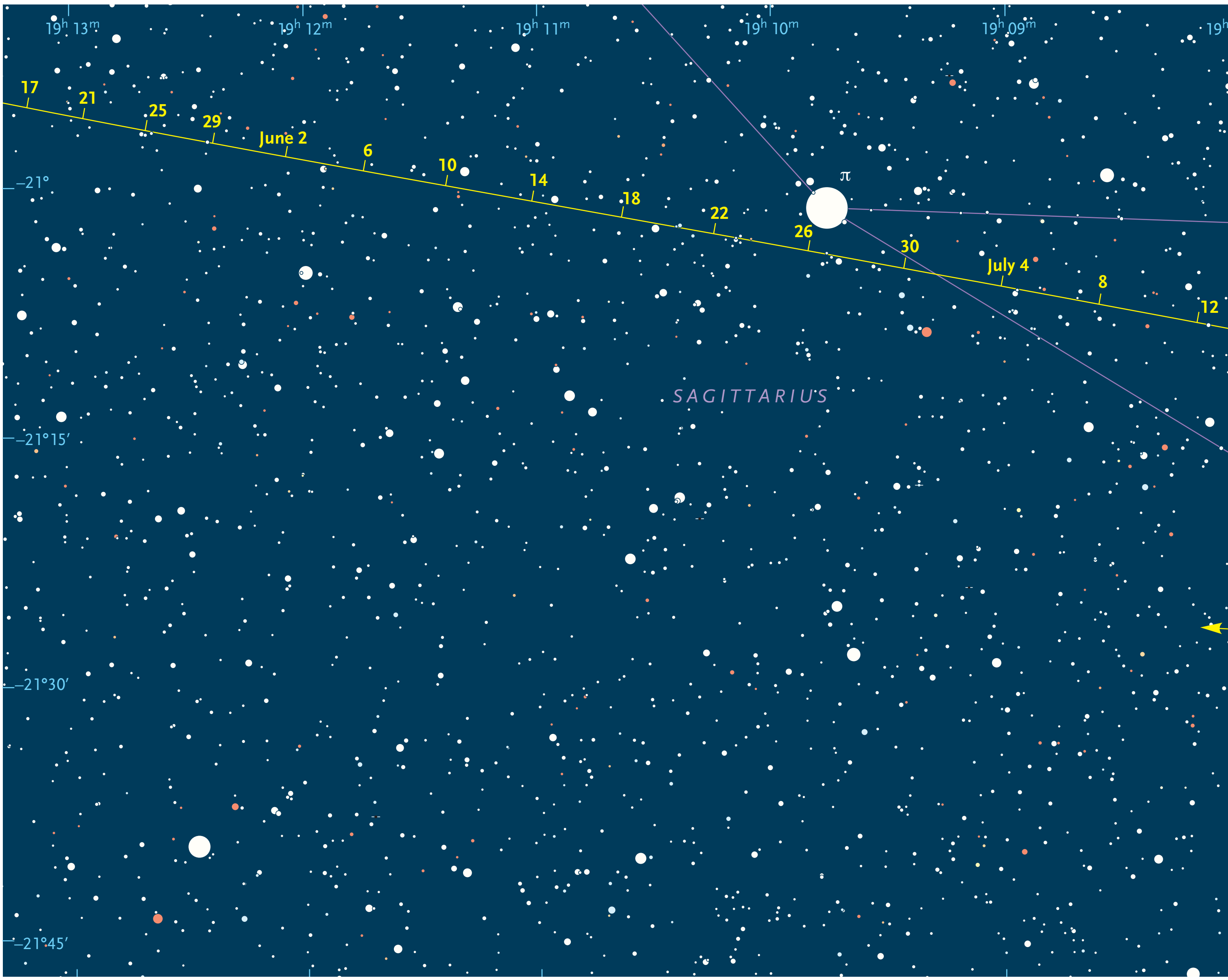
Pluto Has the Last Laugh

For a non-planet, Pluto sure shows some amazing planetary traits.

Ten years after being downgraded from Ninth Planet to "dwarf planet" and "just a large Kuiper Belt object" (yes, for good reasons), Pluto can laugh in astronomers' faces. The New Horizons flyby a year ago — data are still trickling back through the spacecraft's slow link — has revealed that this supposedly dead ice-asteroid beats some of our favorite planets at their own game.

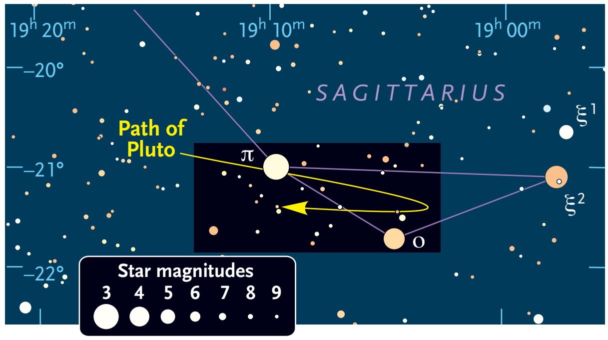
Multifarious Pluto, in exaggerated color.
NASA / JHUAPL / SWRI

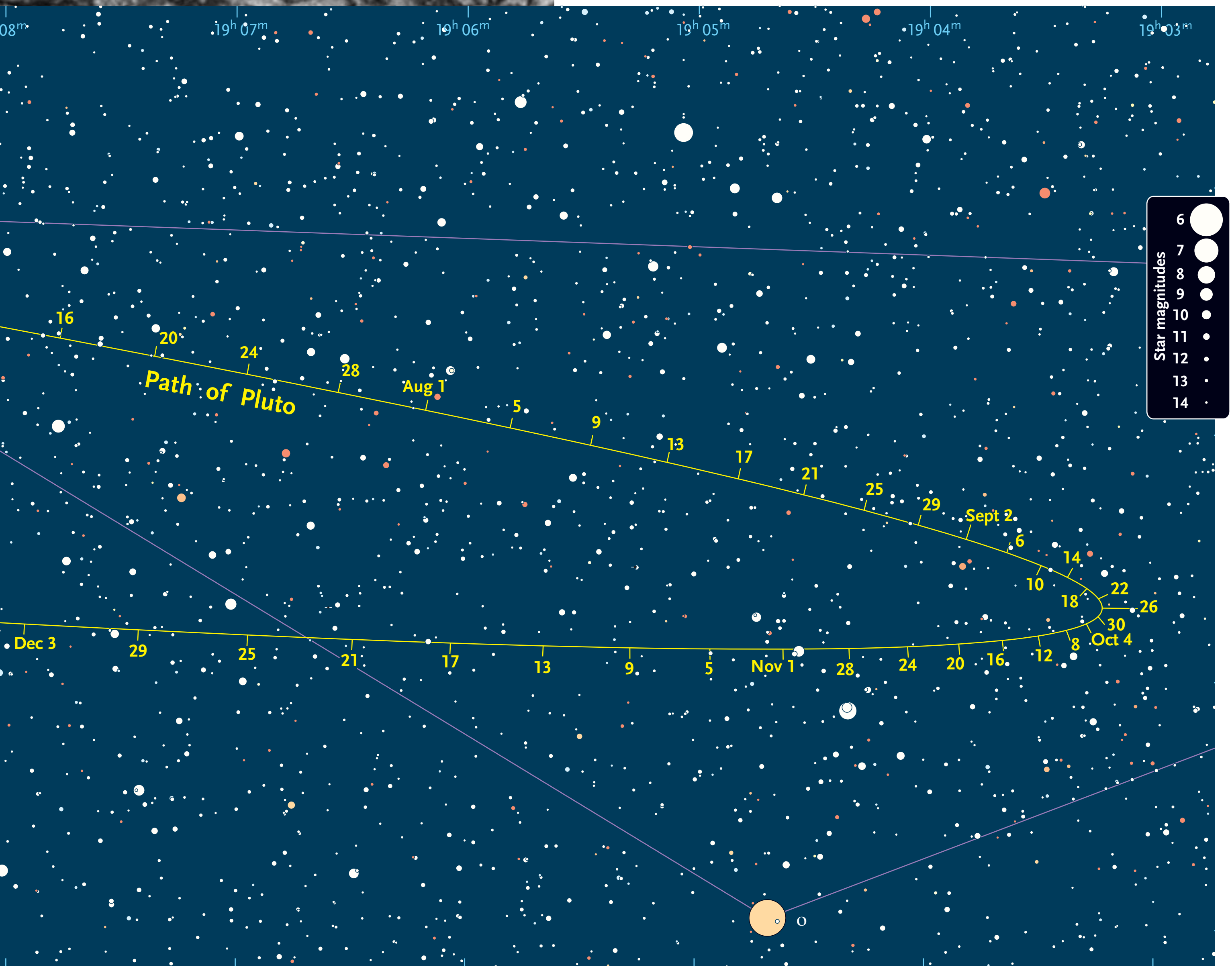
Pluto is more geologically active than Mercury or Mars, sporting a giant, recently formed plain of upwelling frozen nitrogen. Unlike Mercury, Pluto has a thin but significant atmosphere. The atmosphere displays some 20 scenic layers of haze at high altitudes, and low-lying hazes as well that give sunset landscapes an eerily

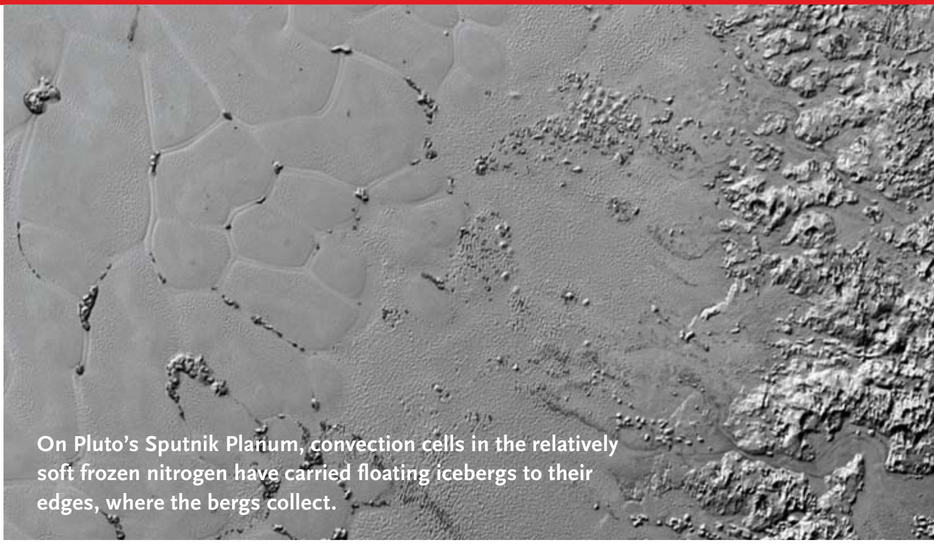


Left: **This frozen-nitrogen lake on Pluto was once apparently liquid. It seems to lie in a larger dry lakebed with older shorelines. The lake is 20 miles (30 km) long.**

NASA / JHUAPL / SWRI







On Pluto's Sputnik Planum, convection cells in the relatively soft frozen nitrogen have carried floating icebergs to their edges, where the bergs collect.

NASA / JHUAPL / SWRI

Earthlike appeal. There are signs of wind-blown dunes on the plains.

And Pluto has a hydrological cycle! Nitrogen sublimates from the frozen sea, condenses onto mountains as a relatively soft solid, and flows back to the sea in long glaciers. Pluto thus joins only Earth and Saturn's moon Titan in having volatiles cycling from "sea" to atmosphere to land and flowing back to the sea.

Pluto's great plain also contains frozen methane and carbon monoxide. Somehow, it's heated from below: much of the plain displays convection cells on its surface. Upwelling material has carried floating water-ice bergs, which broke off from the water-ice mainland, to the edges of the convection cells, where they pile up in clumps and lines.

And there seems to be at least one lake of frozen nitrogen that was once *liquid*. It's about 20 miles (30 km) long in what looks like a larger, dry lakebed. Other features suggest the beds of once-running rivers, presumably nitrogen. Again, only Earth and Titan can compete.

How could liquid nitrogen have ever existed on the surface? Planetologists modeling long-term changes in the tilt of Pluto's rotation axis and the evolution of its orbit find that the atmosphere, with only 0.0001% of Earth's sea-level pressure now, could reach 2% to 25% of Earth's pressure periodically, most recently just 900,000 years ago (see page 10).

The biggest mystery is the internal heat source that drives Pluto's geologic activity. This little world had every reason to freeze up solid early in the solar system's history.

Which makes us wonder: will the other kings of the Kuiper Belt — Eris, Makemake, Haumea, and the rest — prove to be just as interesting? No flyby missions for any of them are on the horizon.

In any case, backyard astronomers have renewed reason to add Pluto to their life list of amazing objects observed.

Taking the Challenge

Pluto is *really* difficult. It's about magnitude 14.3 this season (opposition is on July 10th), and it's losing another tenth of a magnitude every few years as it creeps farther from both Sun and Earth. It's also near the most southern part of the ecliptic, at declination –21°, dreadful for us northerners, especially if there's any light pollution at all toward the south. Pluto won't stop creeping southward until 2030, reaching nearly declination –24°. And it won't stop fading until reaching magnitude 16.0 at aphelion in 2112.

The usual advice is that you need at least a 10- or 12-inch telescope even under a very dark, transparent sky. Occasionally we see reports of people beating that requirement. Canadian Pluto follower Murray Paulson, writing in the 2016 *Observer's Handbook* of the Royal Astronomical Society of Canada, says it's possible to spot Pluto with a sharp 5-inch refractor. He even claims to have caught it once with a 3.7-inch refractor "with great difficulty, eyestrain, and over an hour of painstaking star-hopping." But that was "some years ago" when Pluto was brighter and higher.

To give it a go, use our charts on the previous pages. Pluto is at the Teaspoon of Sagittarius. On the two small key charts, black rectangles show the area covered by the next chart up. The big chart, not quite 1° tall, shows stars to magnitude 14.5. Ticks there mark Pluto's position at 0^h UT every four days.

As you narrow in on the right spot, switch to your highest magnification. Drape a dark towel over your head and eyepiece to cut out stray light; you'll need all the dark adaptation you can get. Keep your eyes in deep darkness for at least an hour beforehand; plan to try for Pluto near the end of an observing session.

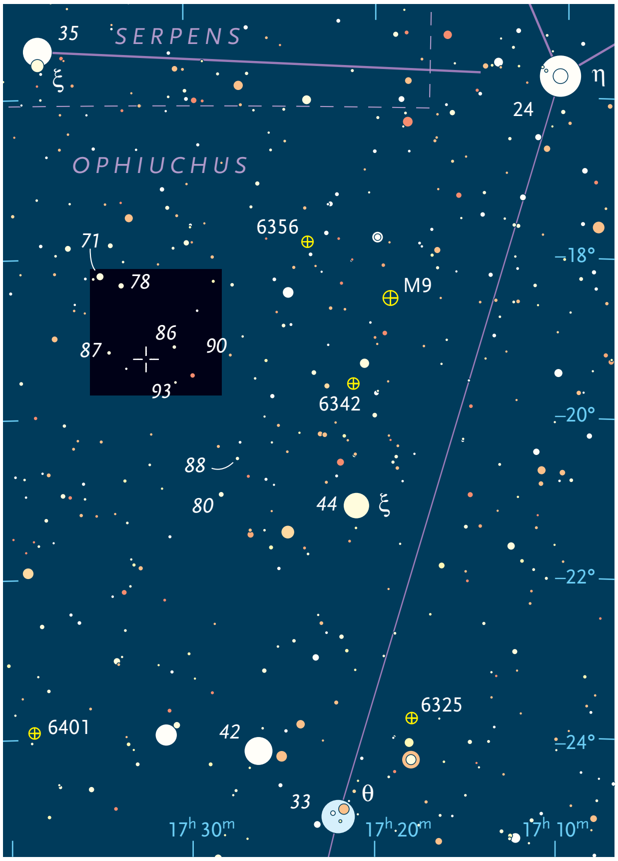
Once you've pinpointed the exact spot in your eyepiece, spend lots of time looking and looking. Your goal is to catch at least three or four pretty definite glimpses. And it's a good idea to check back the next night to confirm that the thing you saw has moved.

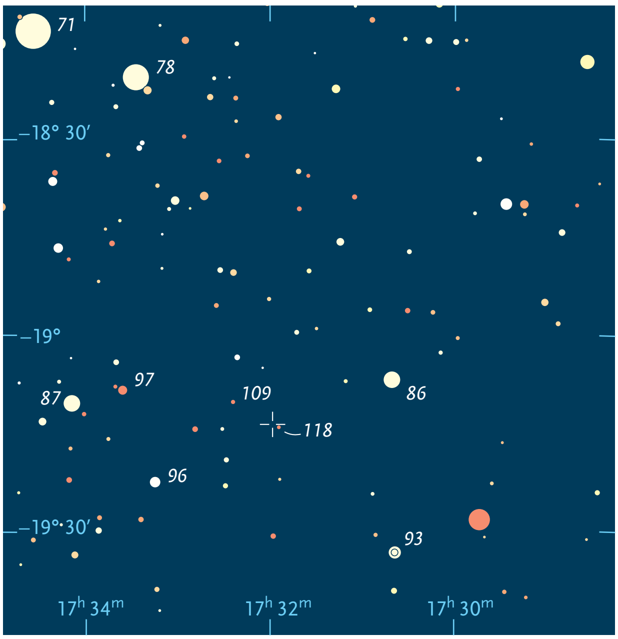
Of course, it takes much less aperture to record Pluto in pictures. But purists will always insist on unmediated photons to the eyeball.

July Meteors

After a six-month lull, meteor-shower activity begins to pick up in the second half of July. Several weak, long-lasting showers with radiants in the late-night southern sky should each produce several meteors visible per hour late at night: mainly the southern Delta Aquariids but also the Piscis Austrinids and Alpha Capricornids. You may also notice an occasional early Perseid showing up.

The Alpha Capricornids, which originate from Comet 169P/NEAT, stand out for being unusually slow-moving and often bright. You may see five or ten of these per hour in the last week of July under ideal conditions.





Ophiuchus stands in the south over Scorpius on July evenings, as shown on our all-sky constellation map on pages 42–43. There you'll find 2nd-magnitude Eta (η) Ophiuchi right at the map's crease. Starting from Eta, use the charts here to star-hop to the repeating nova's precise location. The 11.8-magnitude star on the closeup chart lies 76″ west of the point to watch.

The Nova Ophiuchi Watch

When Nova Ophiuchi 1998 erupted to 10th magnitude in June of that year, no record existed of any previous outburst at its location. But its behavior and spectrum hinted that it might be a recurrent nova — so Ashley Pagnotta, Bradley Schaefer, and others searched its location on the century-spanning collections of sky-patrol plates at Harvard College Observatory and Sonneberg Observatory in Germany. They found that indeed, the star had erupted previously: in June 1900.

They then analyzed the "discovery efficiency" for its eruptions, based on the sky-patrol plate coverage. They wrote, "We deduce a recurrence time for V2487 Oph [as it's now known] of approximately 18 years, which implies that the next eruption is expected around 2016."

This prediction is a long shot, but diligent amateurs can be good at catching long shots.

V2487 Ophiuchi normally simmers uneasily at 17th magnitude. If it rises to 10th again some night, you could catch it visually with a 4-inch scope. It's in the legs of Ophiuchus, east of Antares.

Use the charts at left to get in the habit of taking a peek. Five globular clusters on the wide-field chart at top invite you if the nova is missing (and see Sue French's Deep-Sky Wonders, page 54). M9 is magnitude 7.7; the rest are brighter than magnitude 10.6.

Also: could an unknown outburst be lurking on one of your old images of this much-photographed area? Go check. Don't be misled by the 11.8-magnitude star 1.3 arcminutes west of the nova's position.

Someday V2487 Ophiuchi should dazzle the Earth far more brightly. As in all classical and recurrent novae, a white dwarf here is accreting hydrogen from a close companion star. Periodically, the dwarf's fresh new surface material erupts in a runaway hydrogen-fusion reaction. The white dwarf in V2487 Ophiuchi is unusually massive: 1.35 ± 0.01 solar masses. That's close to the Chandrasekhar Limit of about 1.4 solar masses, at which a white dwarf starts to collapse in on itself and explodes completely as a Type Ia supernova.

When that day comes, V2487 Oph should shine down on the world at 1st magnitude or brighter. At the white dwarf's present estimated rate of mass accretion, expect it to happen in about 4 million years.

Aldebaran Occultation

On the morning of July 29th, the bright limb of the waning crescent Moon will occult 1st-magnitude Aldebaran for the southern and eastern US. The event happens in darkness for Texas and surrounding areas, in twilight for much of the Midwest and South, and after sunrise farther northeast.

Some times: at **Austin,** *disappearance* 4:39 a.m. CDT, *reappearance* 5:19 a.m. CDT; **Atlanta,** *d.* 5:48 a.m., *r.* 6:40 a.m. EDT; **Miami,** *d.* 5:33 a.m., *r.* 6:43 a.m. EDT; **Pittsburgh,** *d.* 6:11 a.m., *r.* 6:44 a.m. EDT; **Washington DC,** *d.* 6:05 a.m., *r.* 6:53 a.m. EDT; **Boston,** *d:* 6:20 a.m. EDT, *r.* 7:03 a.m. EDT.

The Moon will also occult the star-pair Theta[1] and Theta[2] Tauri, magnitudes 3.4 and 3.8, about three hours earlier (in darkness with the Moon much lower) for parts of the East and Northeast.

For all three occultations, find timetables for many cities at **lunar-occultations.com/iota/bstar/bstar.htm**. ✦

Filters for Enhancing the Planets

These affordable observing accessories can bring out details when you observe bright planets.

S&T: SEAN WALKER / SOURCE: TELESCOPES.NET

Colored filters are useful aids when viewing the planets telescopically. They're sold both individually and in sets.

Veteran observers have long maintained that the eye can be trained to see details on the planets that elude the novice. But sometimes even the best-trained eye can use a bit of help at the eyepiece.

For more than a half century, color filters have been indispensable tools for visual observers of the planets. Most of the filters available today are discs of tinted glass mounted in cells that thread into the barrels of standard 1.25- or 2-inch eyepieces. They employ the numerical designations of the Kodak Wratten series of gelatin filters, originally developed for photographic applications more than a century ago.

In recent years, interference filters — produced by the vacuum deposition of multiple thin layers of dielectric films on glass — have appeared on the market. These filters offer higher overall light throughput and more complex spectral properties than the tried-and-true Wratten series. But the latter are available in far greater variety and still provide an inexpensive way to improve your views of the planets.

This spring and summer the southerly declinations of Mars and Saturn mean that, for observers in mid-northern latitudes, neither planet will rise far above the southern horizon. This long light path through Earth's turbulent atmosphere presents daunting challenges for telescopic observers, but an additional difficulty arises that you can avoid by using specific filters.

When you view a planet telescopically at a modest altitude above the horizon, its disk exhibits blue and red fringes along its top and bottom limbs. This phenomenon, known as *atmospheric prismatic dispersion,* results because the higher refractive index of air at shorter wavelengths causes the blue component of the image to be lifted to a greater extent than the red component. At an altitude of 30°, the separation between blue and red light is about 1 arcsecond, the resolution limit of a 4½-inch telescope. Even at an altitude of 45°, the visible spectrum smears out over 0.6 arcsecond, the resolution limit of an 8-inch telescope.

By reducing the intensity of blue light, yellow (Wratten 12 and 15) and yellow-green (Wratten 11) filters sharpen images of low-lying planets and permit you to see finer details. These filters are also invaluable for eliminating the defocused blue and violet light that produces the objectionable purple fringing formed by refractors with achromatic lenses.

The principal benefit of color filters is enhancing contrast. With rare exceptions, planetary markings have delicate, pastel hues — not the vivid, saturated colors that appear in the vast majority of spacecraft and webcam images so often seen these days. Color filters can dramatically improve the contrast and visibility of features that differ even slightly in hue. A reddish feature, for example, reflects red light but absorbs green and blue

ORION TELESCOPES & BINOCULARS

A variable polarizing filter lets you "dial in" the optimum brightness for viewing the brilliant disk of Venus or the Moon.

light, so it will appear bright through a red filter but dark through a green or blue filter.

Here then is an object-by-object guide for using filters when observing the four most rewarding planetary targets in the solar system.

Venus

Enveloped by highly reflective clouds that have an apparent surface brightness almost 10 times greater than the full Moon's, Venus usually appears as featureless as a frosted light bulb unless you take steps to reduce its intense glare. Low-contrast markings on a uniform background are best discerned under moderate levels of illumination, an attribute of human perception that psychologists call the *Weber-Fechner law.* So just reducing the intense brightness of Venus often reveals faint, diffuse markings that would otherwise elude detection.

The simplest way to reduce glare is to use a neutral-density filter. Better yet, get a variable polarizing filter. An indispensable tool for observing Venus (or the Moon), this device consists of a pair of identical polarizing filters in a rotating ring mount. Each polarizer acts like a miniature picket fence that permits only light waves vibrating in the direction of the pickets to pass. When their polarization axes are parallel, they transmit the most light (typically at about 40%). But turn one polarizer so its axis is perpendicular to the other's, and virtually no light gets through. You'll be able to adjust the brightness of the image precisely over a broad range simply by rotating one filter with respect to the other — much like operating a dimmer switch.

The dazzling cloud canopy of Venus usually appears featureless unless you use a neutral-density or variable polarizing filter to reduce its intensity (as at right).

The windswept features in the atmosphere of Venus are most prominent in the ultraviolet region of the spectrum (as imaged at left). The eye can't see those wavelengths, but some cloud details are visible (with reduced contrast) with the aid of a deep blue or violet filter (as at right).

S&T: SEAN WALKER (4)

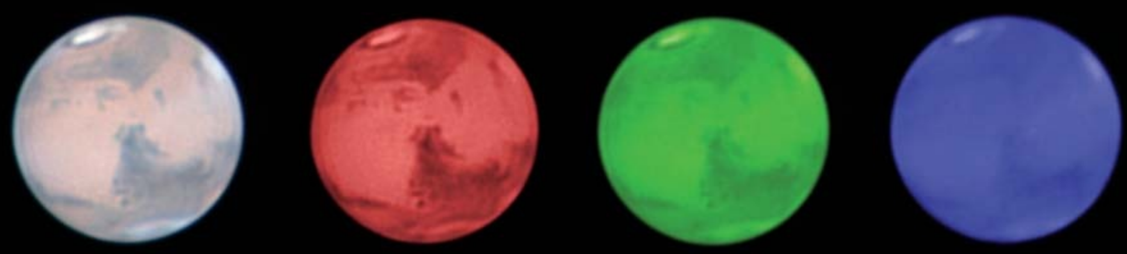
Even with its dazzling brilliance sufficiently subdued, the cloudscape of Venus is extremely bland but rarely featureless. You can often make out bright polar hazes known as "cusp caps," occasionally surrounded by dusky collars. Many reports suggest that these features are best seen using a green (Wratten 56 or 58) filter combined with a neutral-density or variable polarizing filter. Seen in blue and violet light, the caps tend to be lost in the general brilliance of the planet's limb.

In 1927 Mount Wilson Observatory astronomer Frank Ross photographed Venus through an ultraviolet (UV) filter that transmitted wavelengths of 340 to 400 nanometers. To his surprise, the images captured a host of rapidly changing features caused by localized concentrations of a UV-absorbing substance high in the planet's cloud deck. The UV absorber imparts a very subtle yellow cast to some of the planet's clouds, normally perceived as pure snow white due to their dazzling brilliance. As Harvard astronomer William H. Pickering once noted, "The color is strikingly shown if we view Venus by daylight in the telescope while our terrestrial clouds are crossing its disk."

The Venusian markings take the general form of diffuse, dusky bands at middle latitudes running roughly perpendicular to the terminator. You'll often see an equatorial band, sometimes sporting a diverging forked tail that resembles a horizontally aligned letter Y or the Greek letter phi (ψ). A C-shaped feature, occasionally present near the limb, occurs when that diverging fork is distorted by foreshortening as it rotates onto the disk.

The contrast of the ultraviolet markings on Venus is greatest at a wavelength of 340 nm, well beyond the threshold of human vision. Seen at 400 nm, the shortest wavelength perceptible to most of us, their contrast drops by a factor of five.

For visual observers, the Wratten 47 violet filter is widely reputed to offer the best hope of glimpsing the UV features. Unfortunately, the eye's response to the wavelengths transmitted by this dense filter (only 3% of the visible spectrum) is feeble because your retina's cone cells are comparatively insensitive to blue and violet light. Although Venus is a brilliant subject, with a Wratten 47 filter you might find it disappointingly dim even through an 8-inch telescope — and perhaps suffer eyestrain during prolonged observing sessions. Many observers report



Martian surface features stand out far more boldly in red or orange light than in green light. Only clouds high in the planet's atmosphere are evident when viewed in blue light.

S&T: SEAN WALKER

better results using the Wratten 38A blue filter.

At the opposite end of the spectrum, you'll find red (Wratten 23A and 25) and orange (Wratten 21) filters very useful when observing Venus — and Mercury as well — high in the sky during daylight hours because these greatly reduce the apparent brightness of the brilliant blue background sky.

Mars

Color filters will enable you to study the Red Planet's meteorology. Although the Martian atmosphere is very tenuous, it scatters an appreciable amount of light and usually appears virtually opaque at wavelengths shorter than 450 nm (in the deep-blue region of the visible spectrum). In 1871 Lord Rayleigh demonstrated that the scattering of light by gas molecules is inversely proportional to the fourth power of its wavelength. Consequently, violet light at a wavelength of 400 nm is scattered 9.4 times more than red light at 700 nm.

You can use these scattering properties to your advantage. Violet (Wratten 47) and blue (Wratten 38A and 80A) filters restrict observation to the uppermost layers of the Martian atmosphere. These choices accentuate the brightness and sharpen the boundaries of high cirrus clouds, hazes over the planet's poles and along the morning and evening limbs, and the orographic (mountain-generated) clouds that form over the Tharsis and Elysium shield volcanoes.

A rare and poorly understood phenomenon known as the "blue clearing" occurs when the surface features of Mars become visible in blue and violet light for periods of several days or even weeks, usually around the date of opposition. Use Wratten 38A blue and Wratten 47 violet filters to detect and monitor these clearings, which might be limited to only one hemisphere and fluctuate rapidly in intensity.

Features that appear white when unfiltered — and brighter through a green (Wratten 56 or 58) filter than in blue or violet light — correspond to patches of surface frost or low-lying fogs. Dust clouds appear brighter and have sharper boundaries through yellow (Wratten 12 and 15) filters than they do when viewed in green or blue light.

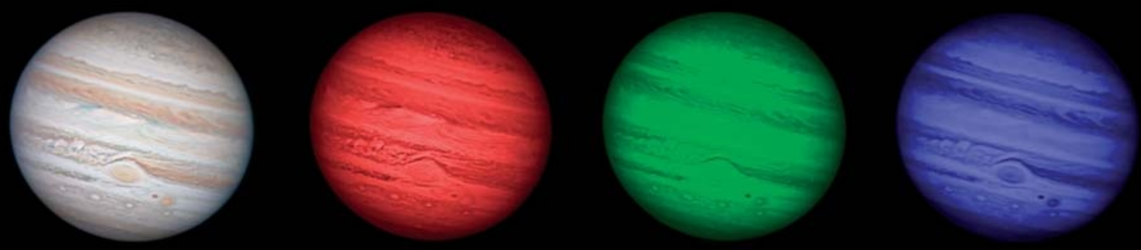
Use Wratten 85 salmon and Wratten 21 orange filters to dramatically increase the contrast between the planet's ochre "deserts" and its duskier "maria." The distinction between these surface features is greatest through red filters: either Wratten 23A or, for apertures greater than 10 inches, the denser Wratten 25. Red light also penetrates the "hood" of haze and cirrus that's usually present over the Martian polar caps, sharpening its boundaries and revealing its true extent.

Some of the most aesthetically pleasing views of Mars are provided by the Wratten 30 magenta filter, which transmits both red and blue light at the opposite ends of the visible spectrum while blocking yellow-green

Characteristics of Filters for Planetary Observing

Wratten number	Color	Visible-light transmission	Dominant wavelength (nm)
25	Red	14%	617
23A	Light Red	25%	606
85	Salmon	68%	595
21	Orange	46%	589
15	Deep Yellow	66%	583
12	Yellow	74%	576
8	Light Yellow	83%	572
11	Yellow-Green	40%	550
56	Light Green	53%	552
58	Green	24%	533
82A	Very Light Blue	73%	476
80A	Light Blue	29%	479
38A	Deep Blue	17%	478
47	Violet	3%	463
30	Magenta	27%	420 & 602

The filters discussed in this article offer a variety of enhancements. Those with low transmission values work best (or only) with larger-aperture telescopes.



Jupiter's Great Red Spot nearly disappears in red light, but it becomes increasingly prominent at shorter wavelengths. Conversely, the blue festoon on the North Equatorial Belt's southern edge darkens dramatically in red light.

Saturn's azure polar hood is sharply delineated in red light but subdued in blue. A green filter brings out belt structure in the planet's tropical and temperate latitudes.

S&T: SEAN WALKER (2)

wavelengths, simultaneously enhancing the contrast of surface and atmospheric features. Baader Planetarium's Contrast Booster and Orion's Mars Observation Eyepiece Filter have dielectric coatings with similar spectral characteristics.

Jupiter and Saturn

Although both the warm hue and the intensity of the Great Red Spot vary markedly over the years (*S&T:* Mar. 2016, p. 18), the visibility of Jupiter's most famous feature invariably improves when you use a light blue (Wratten 80A or 82A) filter. Blue filters also selectively darken the belts' ruddy hues, increasing their contrast with the surrounding zones and accentuating bright features within the belts like ovals and rifts.

The blue festoons that protrude into the light-toned Equatorial Zone from the edges of the adjoining equatorial belts and many features at high latitudes darken dramatically through yellow (Wratten 8, 12, and 15), orange (Wratten 21), and red (Wratten 23A) filters. Yellow-green (Wratten 11) and light-green (Wratten 56) filters often give the most pleasing overall views.

Due to its greater distance from the Sun, Saturn has a colder upper atmosphere, and consequently the hues of its cloudtops are muted by an overlying murky haze of photochemical smog. The planet's belts typically appear a pale greyish brown, while its dusky polar regions feature a cool palette of colors ranging from olive green to teal, aquamarine, and azure blue (*S&T:* July 2015, p. 54). With an apparent surface brightness only 30% that of Jupiter, Saturn is too feebly illuminated to permit the use of dense color filters. Yellow (Wratten 8 and 12) filters invariably improve contrast and definition, while many observers prefer the Wratten 11 yellow-green filter to further selectively darken the warm tint of Saturn's belts. Use the Wratten 82A very-light-blue filter for sharpening the boundaries between belts and zones.

Filters won't result in startling revelations at the eyepiece, but few accessories offer more "bang for the buck." A comparatively modest investment in a well-chosen set of a half dozen color filters will pay rich dividends by allowing you to coax the best possible performance from your telescope. ✦

The Moon • July 2016

Phases

NEW MOON
July 4, 11:01 UT

FIRST QUARTER
July 12, 0:52 UT

FULL MOON
July 19, 22:57 UT

LAST QUARTER
July 26, 23:00 UT

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

Apogee	July 13, 5h UT
404,269 km	diam. 29′ 34″
Perigee	July 27, 12h UT
369,662 km	diam. 32′ 20″

Favorable Librations

Mare Humboldtianum	July 7
Bailly (crater)	July 18
Lacus Veris	July 21

Starry Swarms

Tour the great star cities of southern Ophiuchus.

There is a certain attraction in these far-away glimpses of starry swarms, for they give us some perception of the awful profundity of space. When the mind is rightly attuned for these revelations of the telescope, there are no words that can express its impressions of the overwhelming perspective of the universe.

— Garret P. Serviss, *Pleasures of the Telescope*, 1901

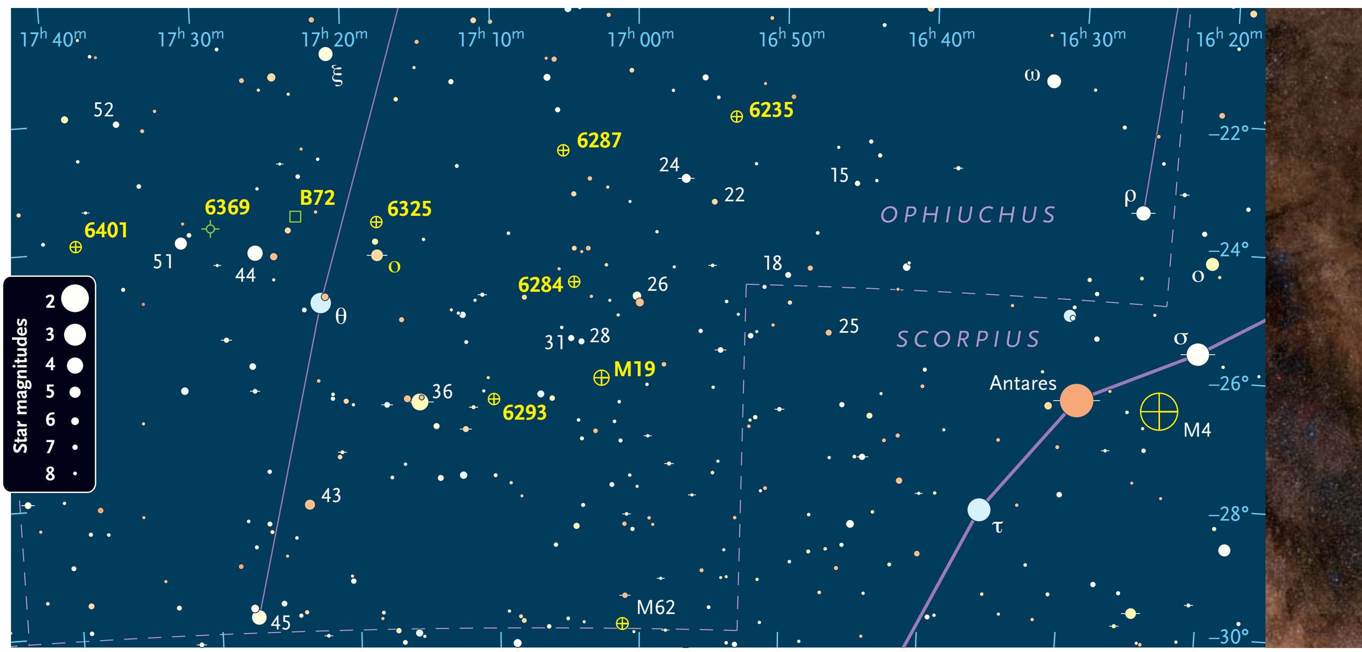
Serviss penned these words of awe in his discussion of the globular clusters that grace our sky at this time of the year. Among them he included four clusters arrayed in the shape of a backward L in the far southern reaches of Ophiuchus.

The quartet's brightest cluster is **Messier 19**, the only one to unveil stars through the scopes piloted by Serviss. M19 is quite simple to find because it lies due east of Antares. If your telescope has an equatorial mount, you can simply sweep eastward from Antares until you bump into it. If not, Earth can find it for you. Center Antares in a low-power field of view, and 33 minutes later the world will have turned far enough around its axis to point your scope toward the cluster.

M19 is rather alluring in my 105-mm refractor. At 87× the tenuous 6′ halo encloses a bright 3½′ core that's distinctly oval north-south. Several stars spatter the cluster, including a 12th-magnitude foreground star slightly northeast of the core. At 127× a generous dusting of stars emerges, and the core enfolds a tiny, blazing heart. Through my 10-inch reflector at 213×, numerous suns adorn the 8′ halo and 3½′ × 2½′ core.

Dropping the magnification of the 105-mm scope to 17×, I can fit M19 in the same field with two of the other clusters in the backward L. **NGC 6293** sits at the end of the L's short bar, and **NGC 6284** is at the middle of its long bar, each much fainter than M19 and about 2′ across with a brighter center. At 127× NGC 6284 exhibits slight mottling. The core is about one-third the cluster's diameter, and its brightest region is elongated, tipped north-northeast, and punctuated by a tiny, intense nucleus. A few faint field stars sparkle just beyond the borders of the halo.

In the 10-inch scope at 115×, NGC 6293 displays quite a few very faint stars down to its vivid and coarsely mottled ½′ hub. The cluster remains fairly bright out to a diameter of 1½′, and the surrounding halo reaches about 2½′ before fading into the background sky. NGC



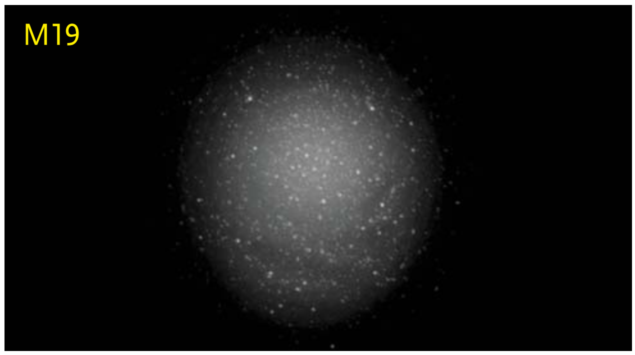
6293 is a lovely sight at 213×, boasting many minuscule points of light. At 115× NGC 6284 appears grainy and a bit smaller than NGC 6293, and a magnification of 213× discloses a smattering of extremely faint stars.

What determines whether you see stars dotting each cluster? A significant factor in this part of the sky is field contamination. Even if the cluster's brightest stars are too dim for your telescope, you may see superimposed stars from the rich foreground of the Milky Way. Among globular clusters, the brightest stars have about the same luminosity, but their apparent magnitude largely depends on distance. At 29,000 light-years, M19's brightest star is magnitude 13.2. For NGC 6293 we have 31,000 light-years and magnitude 13.4, and for NGC 6284 it's 50,000 light-years and magnitude 14.1.

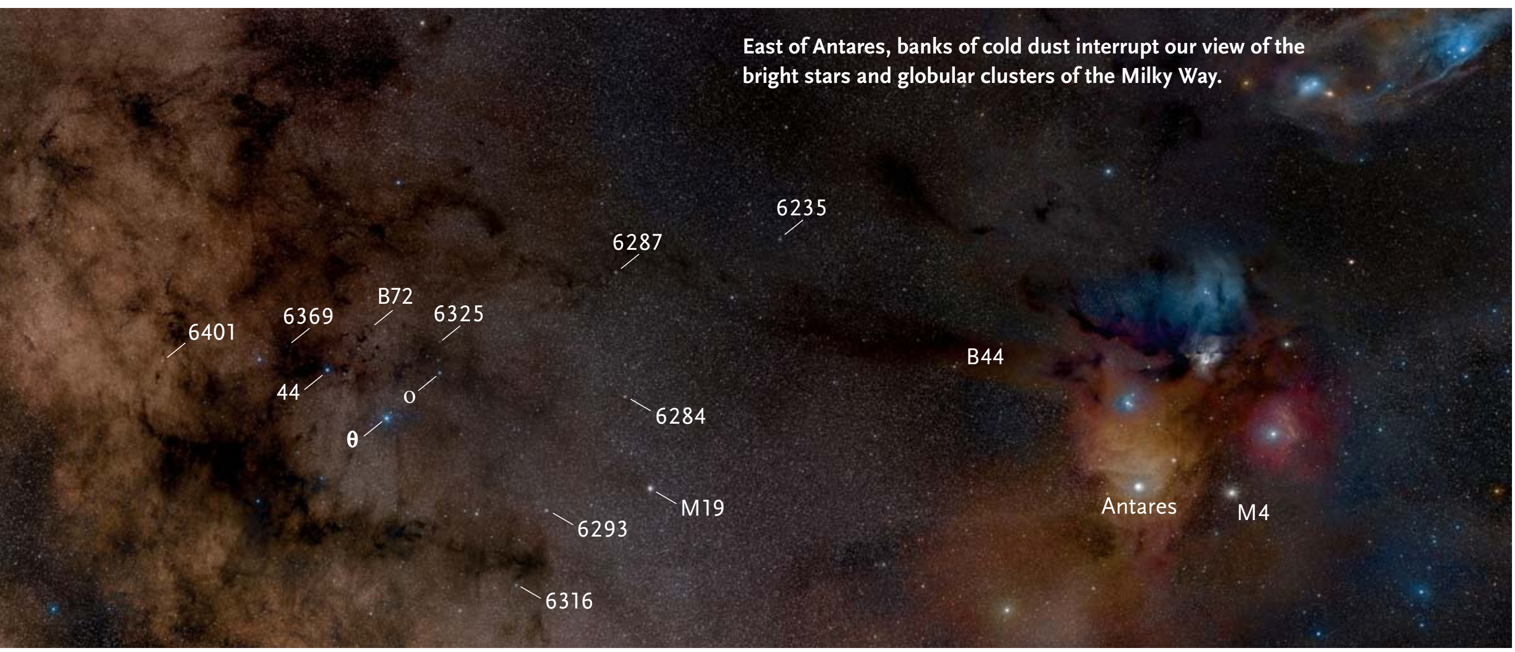
The final globular in the backward L is **NGC 6287**, floating 2.1° north of NGC 6284. It's easy to spot even at 28× with my 105-mm refractor. At 87× it appears fairly bright, slightly mottled, and about 2′ across with a considerably brighter center. Through my 10-inch reflector at 213×, NGC 6287 covers about 2½′. Its grainy fringe is scantily sprinkled with exceedingly faint stars and cocoons a dappled center.

NGC 6287's brightest star is magnitude 14.2, the dimmest we've seen so far even though the cluster is the same distance away from us as NGC 6293. All the globulars in this stretch of the sky are viewed through the dusty plane of our galaxy, which absorbs and scatters some of their light, but the amount of extinction depends on our exact line of sight. The stars in our first three globulars lose about one magnitude to this effect,

When Charles Messier discovered this globular on June 5, 1764, he was unable to discern individual stars. Fred Espenak captured this well-resolved image with a 180-mm f/2.8 astrograph and DSLR camera in two 300-second exposures at f/2.8 and ISO 800.



Bertrand Laville threw 11 inches of aperture at 140× at the globular to complete this delicate sketch while observing at Tivoli, Namibia.



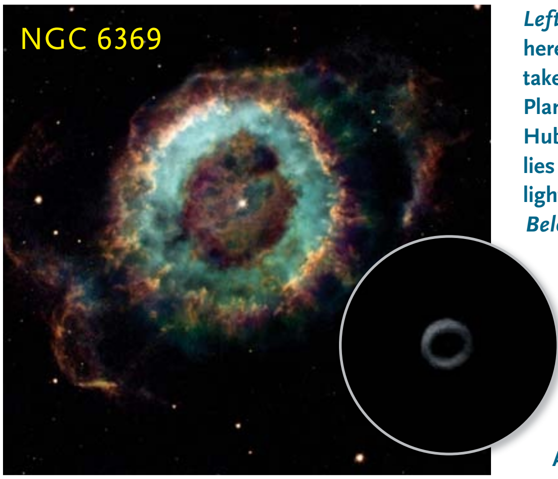
East of Antares, banks of cold dust interrupt our view of the bright stars and globular clusters of the Milky Way.

ROGELIO BERNAL ANDREO

whereas those belonging to NGC 6287 lose nearly two magnitudes.

Moving beyond the clusters mentioned by Serviss, you'll find **NGC 6235** 1.2° northwest of 24 Ophiuchi. It's easily visible in my 105-mm scope at 47×, with an 11th-magnitude star close to its north-northwestern edge. At 87× the cluster is a 3′ globe that grows brighter toward the center. A few extremely faint stars freckle the cluster in the 10-inch scope at 115×, and a dash more emerge at 231×. NGC 6235 is 38,000 light-years distant. Its brightest star is magnitude 14.0, and it suffers one magnitude of extinction.

Our next globular cluster is **NGC 6325**. Look for it 31′ due north of **Omicron (ο) Ophiuchi**, a pretty double with a 5.2-magnitude gold star accompanied by a 6.6-magnitude yellow companion 10″ to its north. The cluster is just a tiny fuzzspot through the 105-mm refractor at 17×, while at 87× it's a 1½′ ball with a slightly brighter center. In the 10-inch reflector at 115× the cluster becomes a granular 2′ haze. It's little wonder that I couldn't detect stars in this cluster, because its brightest member weakly shines at magnitude 15.2. In this month's tour, NGC 6325 is the closest cluster to us at 25,000 light-years, but its stars undergo 2.8 magnitudes of extinction. The dark nebulae riddling this patch of sky are to blame for this severe brightness loss. It's like looking at the cluster through a sooty window.



Left: **NGC 6369, shown here in a composite image taken by the Wide-Field Planetary Camera 2 on the Hubble Space Telescope, lies about 2,000 to 5,000 light-years from Earth. *Below:* Bertrand Laville sketched the ghostly figure of NGC 6369 as seen through a 450-mm Dobsonian at 257× while he was observing in San Pedro de Atacama, Chile.**

Objects in Ophiuchus

Object	Type	Mag(v)	Size/Sep	RA	Dec
M19	Globular cluster	6.8	17′	$17^h\ 02.6^m$	–26° 16′
NGC 6293	Globular cluster	8.2	8.2′	$17^h\ 10.2^m$	–26° 35′
NGC 6284	Globular cluster	8.8	6.2′	$17^h\ 04.5^m$	–24° 46′
NGC 6287	Globular cluster	9.4	4.8′	$17^h\ 05.2^m$	–22° 43′
NGC 6235	Globular cluster	10.0	5.0′	$16^h\ 53.4^m$	–22° 11′
NGC 6325	Globular cluster	10.3	4.1′	$17^h\ 18.0^m$	–23° 46′
ο Oph	Double star	5.2, 6.6	10.0″	$17^h\ 18.0^m$	–24° 17′
B72	Dark nebula	—	34′ × 16′	$17^h\ 23.8^m$	–23° 42′
NGC 6369	Planetary nebula	11.4	38″	$17^h\ 29.3^m$	–23° 46′
NGC 6401	Globular cluster	9.5	4.8′	$17^h\ 38.6^m$	–23° 55′

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.

Barnard 72 is a unique scrap of inky dust sitting 1.3° east of NGC 6325. The dark nebula's sinuous form earns B72 its common name, the Snake Nebula, as well as a place among favorites for imagers (see page 41). My home sky isn't dark enough for a pleasing view of the nebula, but from the northern reaches of New York's Adirondack mountains with my dad's old 6-inch reflector, I can see the most prominent part as a 17′-tall S charcoaled on the backdrop of the Milky Way.

Continuing our eastward trek, we'll encounter the planetary nebula **NGC 6369**, also known as the Little Ghost, perched 31′ west-northwest of 51 Ophiuchi. It's quite petite in my 105-mm scope at 47× but stands out well with a narrowband nebula filter at 122×. At 166× with an O III filter, the 10-inch scope transforms the nebula into a splendid little ring. The annulus is brighter along its northern rim, which contains a nearly stellar bright spot. Folks with larger scopes might like to try for the nebula's 15.1-magnitude central star.

We'll conclude our deep-sky tour with one last globular cluster, **NGC 6401**, found 1.6° east of 51 Ophiuchi in an area rife with dark nebulae. Through the 105-mm scope at 47×, the cluster is too small to reveal features, but at 87× I can see that it has a brighter core. At 127× the NGC 6401 spans 1½′, and a 12th-magnitude foreground star is conspicuously superimposed on the east-southeastern fringe of the core. Even my 10-inch scope at 213× won't pry any stars from the haze, but merely proffers a slight mottling of the 1¾′ glow.

NGC 6401 dwells 35,000 light-years away from us, and its brightest star meets our eyes at a feeble apparent magnitude of 15.2. With so many dusty nebulae threading this region, it's not surprising that NGC 6401's stars are muted by 2.3 magnitudes of extinction.

As Serviss wrote, these starry swarms are sometimes "more interesting for what they signify than for what they show." We know them for the great star cities they truly are, and they teach us about our view through the dusty galaxy that we call home. ✦

Steve Gottlieb

A Herculean Challenge

Test your skills with this ambitious array of galaxies.

Rich galaxy clusters vary significantly in the distribution of galaxy types, the degree of central concentration, and whether there is a single dominant member. In some clusters a central ultra-luminous elliptical (cD-type) holds court over a contingent of lenticular (S0) and E-type galaxies. The Hercules Galaxy Cluster (Abell 2151), on the other hand, is irregular in structure, has no leading member, and abounds with star-forming spirals (roughly 50% of the population). This galactic assemblage includes a wild assortment of edge-on and face-on spirals, merging pairs, and distorted interacting systems.

Abell 2151 is also one of the most distant clusters that can be explored in depth with a 12-inch scope (a few of the brightest members may be visible in an 8-inch), though you'll need dark skies, a detailed chart, and plenty of patience. Keep in mind the photons from these faint fuzzies have been traveling some 500 million years to reach your eyes!

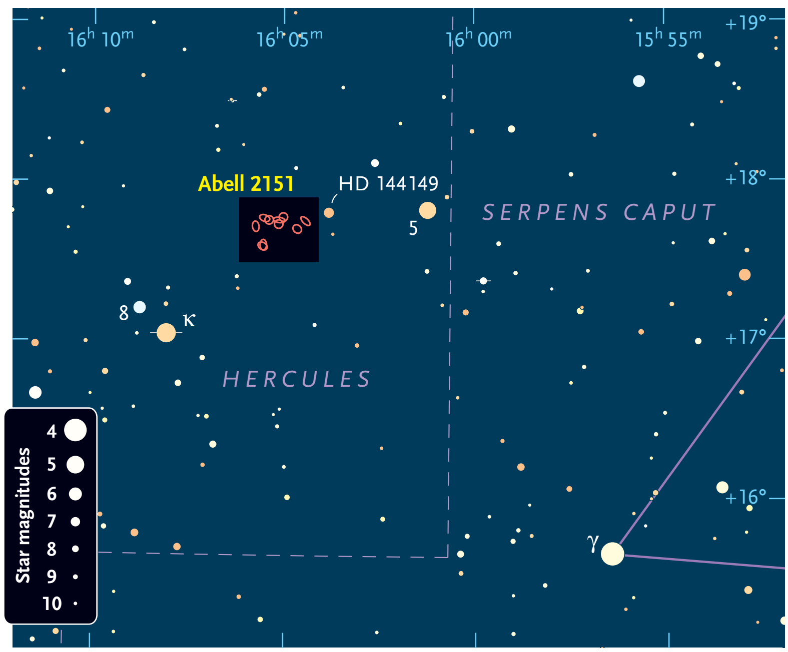
The NASA/IPAC Extragalactic Database (NED, **ned.ipac.caltech.edu**) lists 300 members of Abell 2151 within a 1.5° area. The central 18′ × 6′ region, called Abell 2151C, is the richest region, containing over 15 members from 14th to 15th magnitude. I first tackled the cluster in 1983 through a 13.1-inch reflector but recently used my 18-inch f/4.3 reflector to re-survey the area. Since these galaxies are typically quite small, try using a magnification of 250× or higher if the seeing allows — the boost will increase visibility and help to resolve several close galactic pairs.

The heart of the cluster is a snap to locate. Start at 5th-magnitude 5 Herculis, just east of the distinctive triangular asterism forming the head of Serpens Caput. Then either nudge your scope 37′ due east or star drift for 2½ minutes to 6.8-magnitude HD 144149. The interacting pair **NGC 6040** is just 9′ east-southeast of this star; it anchors a 4′ string of a half-dozen galaxies.

NGC 6040A, a highly inclined spiral, showed as a diffuse oval, elongated 2:1 from southwest to northeast. Occasionally, a star-like nucleus glimmered in the misty patch. I found **NGC 6040B**, a round 15″ fuzz spot, snuggled up against NGC 6040A's south limb. The pair forms Arp 122, from Halton Arp's 1966 *Atlas of Peculiar Galaxies*, and VV 212, from Boris Vorontsov-Vel'yaminov's 1959 *Catalogue of Interacting Galaxies* (*S&T:* Sept. 2014, p. 60). The warped tidal tail of NGC 6040A and knots of young, massive star clusters point to this pair's ongoing interaction.

Next in line is **NGC 6041**, another double galaxy with the designation VV 213. Initially I noticed a single elongated patch extending southwest to northeast. But when the seeing settled, the patch resolved into **NGC 6041A**, a small hazy oval just 15″ × 10″ and **NGC 6041B**, a barely non-stellar companion a mere 20″ southwest. Look for two 10.7- and 13.5-magnitude stars 2′ due south that align nicely with the pair. Despite its modest visual appearance, NGC 6041A is a giant elliptical and one of the most luminous members of the cluster. Its extensive halo may include the cannibalized remains of several of its former neighbors.

See if you can glimpse **IC 1170**, just 1′ west of this twosome. With averted vision it popped into view as a ghostly sliver. The last in this galactic string is **NGC 6042**, a compact 12″ knot with a brighter nucleus. It sits 1.5′ southeast of NGC 6041B and 1.7′ northeast of a prominent 10.7-magnitude star.



Nudge your scope about 8′ east to another short string of three NGC galaxies. **NGC 6043A**, a slightly out-of-round patch, is collinear with two stars about 1′ and 2′ south. I missed **NGC 6043B**, a 16.7-magnitude speck at its southwest edge. If you can spot this toughie, let me know.

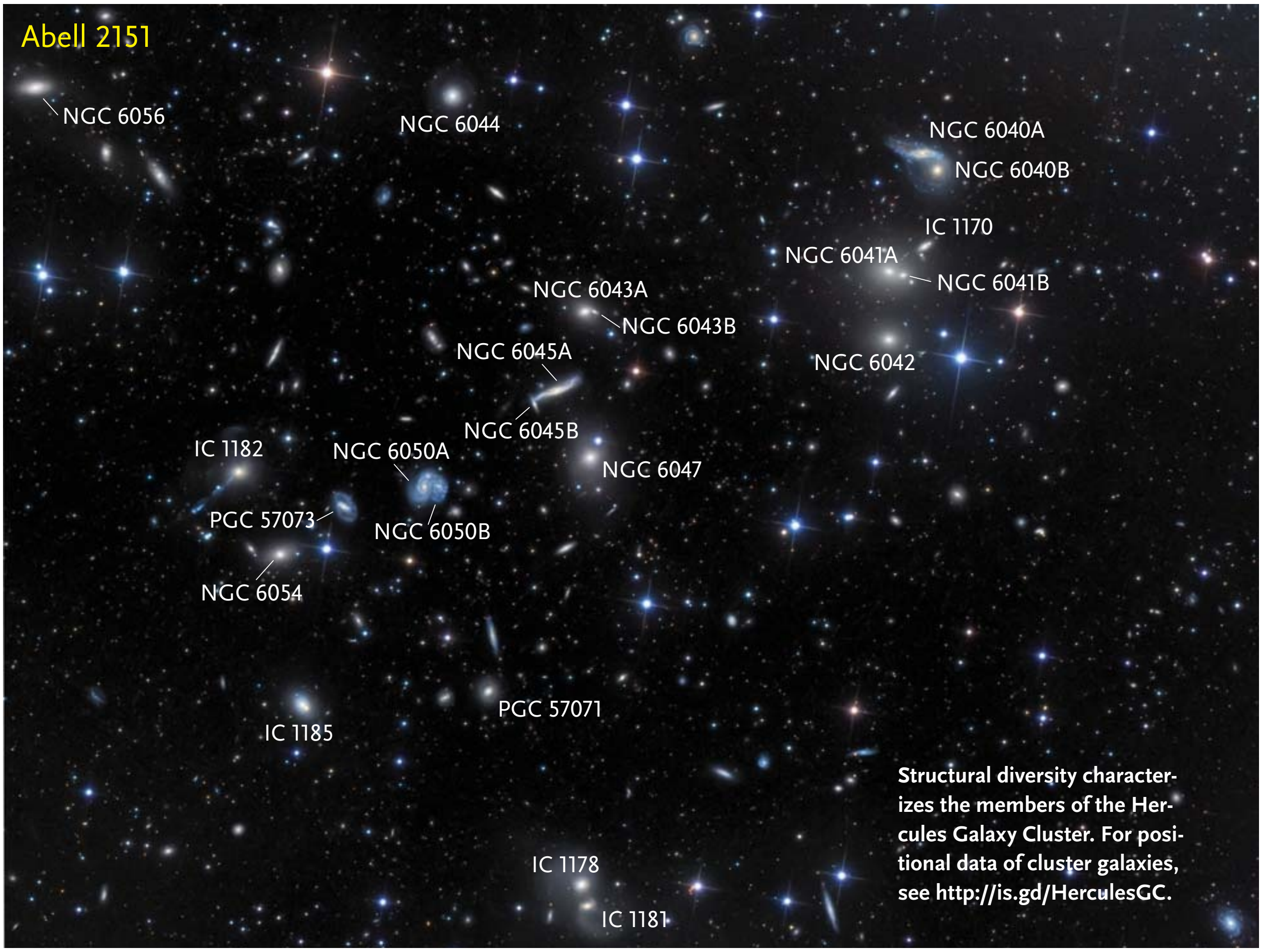
Just 2′ southeast lies **NGC 6045A**, a slender streak 40″ long and ¼ as wide, tipped slightly to the west-southwest. I was unsuccessful with **NGC 6045B**, a minute companion dangling at the eastern tip (the pair forms Arp 71), but I've detected it through my 24-inch as a subtle tail. NGC 6045A has a warped disc resembling a mathematical integral sign, possibly the tidal result of an encounter with a nearby neighbor. **NGC 6047**, just 1.7′ south, is a 15″ fuzz ball that intensifies to the center. A 13.5-magnitude star is nearly pinned to the northwest edge.

Now shift your attention 4′ east of NGC 6045 to the double system **NGC 6050A** and **NGC 6050B** (the latter is often identified as IC 1179). In my 18-inch at 280×, the pair appeared as a 40″ × 25″ hazy region with a slightly uneven surface brightness. In the Hubble Space Telescope images, NGC 6050 reveals itself as a spectacular collision of two spirals (also cataloged as Arp 272 and VV 220) with their arms entwined in a cosmic embrace. Don't expect to cleanly separate this duo — even through Jimi Lowrey's 48-inch f/4 reflector, NGC 6050B appeared fused to its larger partner.

I next spied **PGC 57073**, which lies 2′ east of NGC 6050 and 1′ northwest of a 12.5-magnitude star. Glowing at only 15.2-magnitude, this was a tough 15″ dust bunny. Images, though, show a disrupted galaxy with an irregular outer ring surrounding a blue, star-forming bar. **NGC 6054**, a scant 1′ northeast of the same star, was an easier 15″ × 10″ oval.

Be aware if you plot this pair using amateur software: the western galaxy may be identified as NGC 6054 and the eastern one labeled IC 1183. The ambiguity is a result of imprecise NGC coordinates. But Lewis Swift, who discovered NGC 6054 in 1886, placed the nearby star to the southwest of the "nebula," matching the eastern galaxy.

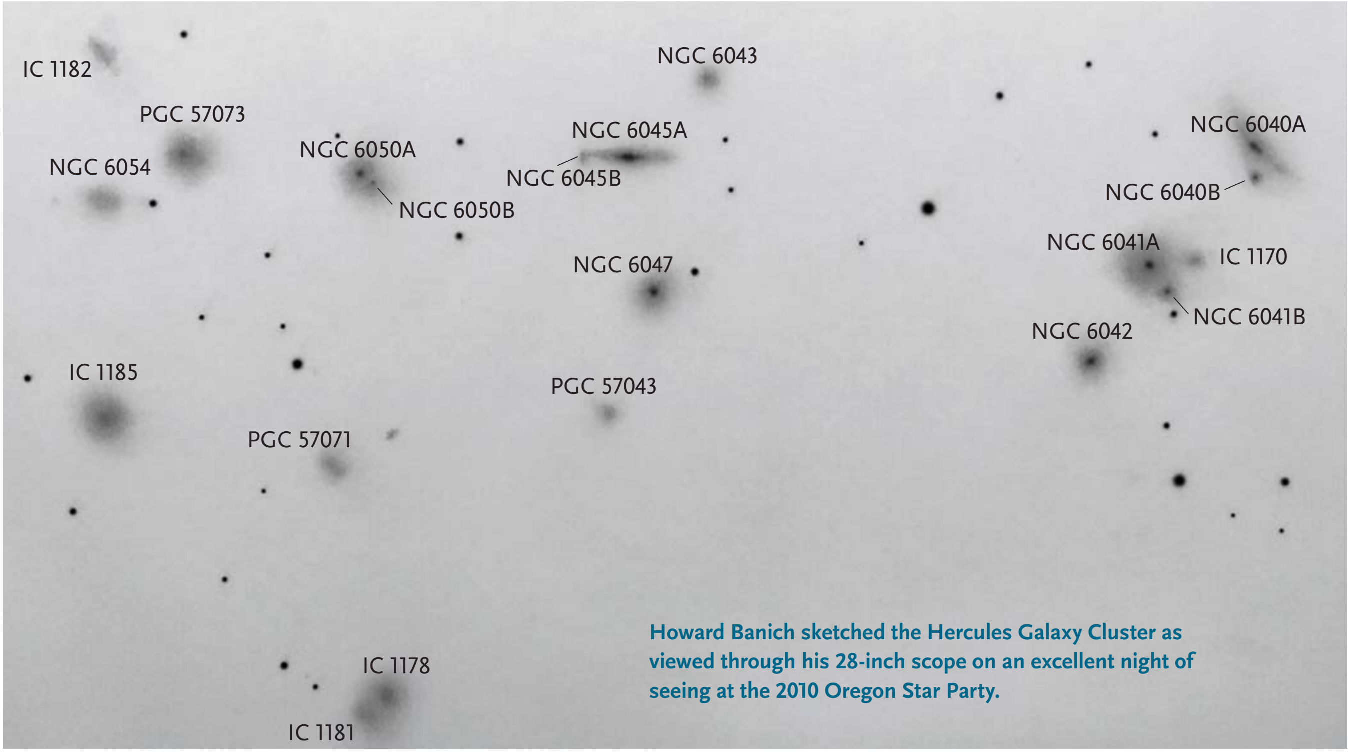
IC 1182, 2′ to the north of NGC 6054, features a weakly concentrated halo. Long known for its peculiar morphology, IC 1182 is a starburst galaxy with emission knots in the central region and an unusual "jet" containing compact knots. Recent studies conclude this activity



KEN CRAWFORD

Structural diversity characterizes the members of the Hercules Galaxy Cluster. For positional data of cluster galaxies, see http://is.gd/HerculesGC.

*Contributing Editor **Steve Gottlieb** completed the entire NGC (visible from northern California) about a year ago. He can be reached at steve_gottlieb@comcast.net.*



Howard Banich sketched the Hercules Galaxy Cluster as viewed through his 28-inch scope on an excellent night of seeing at the 2010 Oregon Star Party.

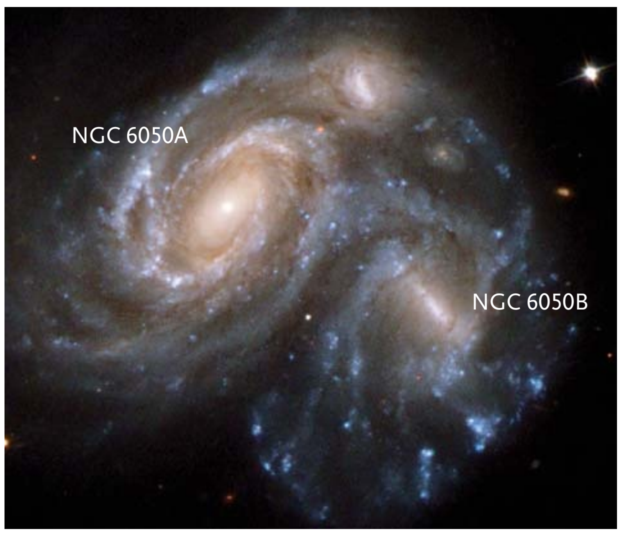
results from a late-stage merger of two systems. A narrow tidal tail from this mash-up extends 1.5′ to the east. Several small blue structures in the tail may contain proto-dwarf galaxies, forming from material ejected in the collision. The only view I've had of one of these knots was through Lowrey's 48-inch.

IC 1185, similar in size to IC 1182, marks the east end of the cluster's central region. I easily picked up this 13.9-magnitude galaxy 3.5′ southeast of NGC 6054; it displayed a bright nucleus embedded in a nearly circular 18″ halo. A 15th-magnitude star is parked 1′ southeast.

We'll end our tour with **IC 1178** and **IC 1181**, found 8′ south-southwest of IC 1185. This interacting duo (Arp 172 and VV 194) glows with striking beauty on images, with two opposing plumes that sweep counterclockwise. Visually, IC 1178 is the more prominent member and sports a sharply condensed center, while IC 1181 is a nebulous smudge just off the south edge.

If you're still in the wandering mood, direct your eyepiece field farther northeast and you'll run into the trio of IC 1192, IC 1193 and IC 1194. Head north from NGC 6045 and you'll encounter a scattering of additional galaxies, including NGC 6044 and 6056. These galaxies lie within the distinct subgroups Abell 2151E and 2151N. Strong evidence suggests the peripheral members are still in the process of collapsing into the cluster's core.

Abell 2151 is just one concentration in the Hercules Supercluster, a chain of Abell galaxy clusters that covers several degrees of sky. On the grandest scale, the Hercules Supercluster is at the east end of the cfA2 Great Wall, discovered in 1989 by Margaret Geller and John Huchra during the Harvard-Smithsonian Center for Astrophysics second redshift survey. This immense filamentary structure spans a mind-boggling 500 million light-years and includes the rich Coma and Leo superclusters. ✦



NASA / ESA / HUBBLE HERITAGE TEAM (STSCI / AURA) / K. NOLL (STSCI)

Spiral galaxies NGC 6050A and NGC 6050B (also cataloged as ARP 272) come together in a dramatic collision, their arms reaching and dissolving into one another.

 Dennis di Cicco

Astro-Tech's 14-inch f/8 Ritchey-Chrétien Telescope

Everything about this telescope looks top-flight — except for the price. Is there a catch?

ALL PHOTOS BY THE AUTHOR

Astro-Tech 14-inch f/8 Ritchey-Chrétien Telescope

U.S. price: $5,795
Astronomics.com

UNFORTUNATELY George Willis Ritchey didn't live to see it happen, but the optical design he codeveloped in the early 1900s proved to be profoundly important to professional and amateur astronomers during the latter half of the 20th century. Clearly gifted, albeit eccentric, Ritchey helped usher in the age of astrophysics working with George Ellery Hale at Yerkes and Mount Wilson observatories. Following his success building Mount Wilson's 60-inch reflector, Ritchey used it to take the finest deep-sky photographs of the day. But he was well aware that coma — the optical aberration that turns stars into seagull-shaped flares away from the center of the field — limited what could be sharply photographed with traditional Newtonian and Cassegrain reflectors.

Around 1910, Ritchey pooled his practical knowledge of telescope optics with the mathematical skills of his Mount Wilson colleague Henri Chrétien, to come up with a Cassegrain design that theoretically produced excellent star images across a wide field. But no funds were available for the construction of a

Astro-Tech's 14-inch f/8 Ritchey-Chrétien telescope is seen here in the author's suburban-Boston backyard observatory mounted on a Software Bisque Paramount MX and fitted with the SBIG STT-8300 CCD camera used for all the accompanying deep-sky images except where noted. As with most open-tube telescopes, a light shroud is recommended if the scope is used around any ambient light sources, including computer screens.

prototype, in part because the primary and secondary mirrors were hyperboloids and thus deemed too difficult to fabricate and test.

Decades passed before a Ritchey-Chrétien scope (or RC for short) was tested photographically on the sky. And it wasn't until 1955, 10 years after Ritchey's death, that a 40-inch RC he built for the United States Naval Observatory was relocated to Arizona and began producing Ritchey's long-promised results. Indeed, the ultimate success of the 40-inch paved the way for the design being adopted for virtually every large-aperture professional telescope made during the next half century, including the Hubble Space Telescope.

In the early 2000s, amateurs too turned to the Ritchey-Chrétien design as they transitioned from film-based to digital astrophotography and wanted large-aperture telescopes capable of delivering quality star images across the digital detectors then becoming available. Those RCs were expensive, but so too were large-format digital cameras, and most amateurs able to afford one could also afford the other.

Today, however, astrophotographers are using a wide range of modestly priced digital cameras, including DSLRs, and that's driving a market for suitable imaging telescopes that are also modestly priced. And for many, the new line of Astro-Tech truss-tube RCs fills the bill. Costing a fraction of what previous RCs cost, some must wonder if the manufacturer cut corners or sacrificed quality. To find out, we borrowed the Astro-Tech 14-inch RC from Astronomics, and I tested it last fall and winter from my suburban-Boston backyard observatory.

Impressive Specs

On paper the AT14RCT looks incredible for a telescope costing $5,795, given that 14-inch RCs in the past were priced well into the 5-digit range. In addition to the carbon-fiber truss tube, a trio of cooling fans for the primary mirror, a dual-speed 3-inch Crayford-style focuser, and a pair of Losmandy-style dovetail mounting bars, the scope features both mirrors made of fused quartz. With the exception of Questar telescopes, this thermally stable material has rarely been offered as an option for amateur scopes (and even in the case of the already pricy Questar, a quartz mirror added a roughly 25% premium to the cost).

Out of the box, the AT14RCT looks every bit as good as its specifications do on paper. The machining is first rate, and the fit and finish excellent. Without the focuser attached, the scope weighs about 65 pounds (29 kg). At its widest part, the tube is 20½ inches (52 cm) across, and excluding the focuser it's 39 inches long.

The scope has a fixed focus, which I measured as falling almost exactly 11 inches outside the back of the telescope. This is more than enough room to fit even complex imaging setups that include, say, a flip mirror, off-axis guider, motorized focuser, filter wheel, and camera. Given that imaging setups can weigh 15 pounds or more, and a guide scope can add a few more pounds, the AT14RCT should be used with a mount rated for at least 90 pounds. That's the suggested limit for Software Bisque's original Paramount MX that I used for all of my testing. It worked well in all but the windiest conditions when I was using a guide scope and very heavy camera.

As detailed in the text, the scope proved to be a delight for visual deep-sky observing even though Ritchey-Chrétiens are most often considered as imaging instruments. The supplied 3-inch Crayford-style focuser was fine for eyepieces and lightweight cameras, but struggled with heavy imaging setups.

I was in for an unexpected treat on my first night. To check the optical collimation, I slipped a high-power eyepiece into the focuser and examined the image of a bright star. The collimation was spot on, so I switched to a low-power eyepiece to see if stars appeared uniform across a larger field. They did. Furthermore, the view was beautiful, with the subtle hues of stars clearly visible — this is after all a 14-inch telescope.

To make a long story short, on more than one occasion I spent an entire night using the AT14RCT with eyepieces. It's a very nice visual telescope, which is something I hadn't considered beforehand given that RCs are mainly promoted for their imaging qualities. The scope has a focal length of 2,834 mm (my measurement), yielding an image scale of 72.7 arcseconds/mm. As such the maximum field of view possible with a 2-inch eyepiece is almost 1° across — pretty decent for a 14-inch Cassegrain system.

Visual observing also highlighted the advantages of the scope's quartz optics. I typically open my observatory roof at least an hour before using any

WHAT WE LIKE:

Excellent optical quality and focus stability

Fused-quartz mirrors with 99% reflective coatings

Rigid carbon-fiber truss tube

WHAT WE DON'T LIKE:

Requires a focuser upgrade for use with heavy cameras (but to be fair, this is clearly stated in the scope's documentation)

The AT14RCT is noteworthy for its remarkable focus stability. Despite falling temperatures, the author never refocused the scope during the 7-hour period when he gathered the red, green, and blue exposures for this view of the spiral galaxy M81.

scope so that the instrument can settle to ambient temperatures. If I don't, sudden temperature changes often distort telescope mirrors enough to make them temporarily unusable. This wasn't the case with the AT14RCT, which continued to perform well optically as the mirrors were cooling. Temperature acclimation, which is sped up by running the fans behind the primary mirror, is still important, because heat plumes rising from the warm mirrors can cause flaring on star images.

Imaging with the AT14RCT

As the astrophotos accompanying this review will attest, the scope produces great images. During one night

This shot of the Crescent Nebula in Cygnus was recorded during a night of unusually good seeing for the author's location. Stars are only about 1½ arcseconds in diameter in this 290-minute exposure made through a hydrogen-alpha filter. All astronomical images in this review were processed by Sean Walker.

with unusually good seeing conditions, I measured star diameters as small as 1½ arcseconds (full-width, half-maximum) in 10-minute exposures. This is exceptionally good performance.

The carbon-fiber truss tube and quartz optics did an outstanding job of maintaining focus stability. On many nights I simply left the focus untouched after it was set at the beginning of the observing session. The image of the grand spiral galaxy M81 at left was captured during a 7-hour period on a chilly night last March. Stars appeared as sharply focused in the final exposures as they did in the first ones. And because this scope has only mirrors and no lenses, all wavelengths of light come to the same focus; there is no need to tweak the focus when shooting through any color filters.

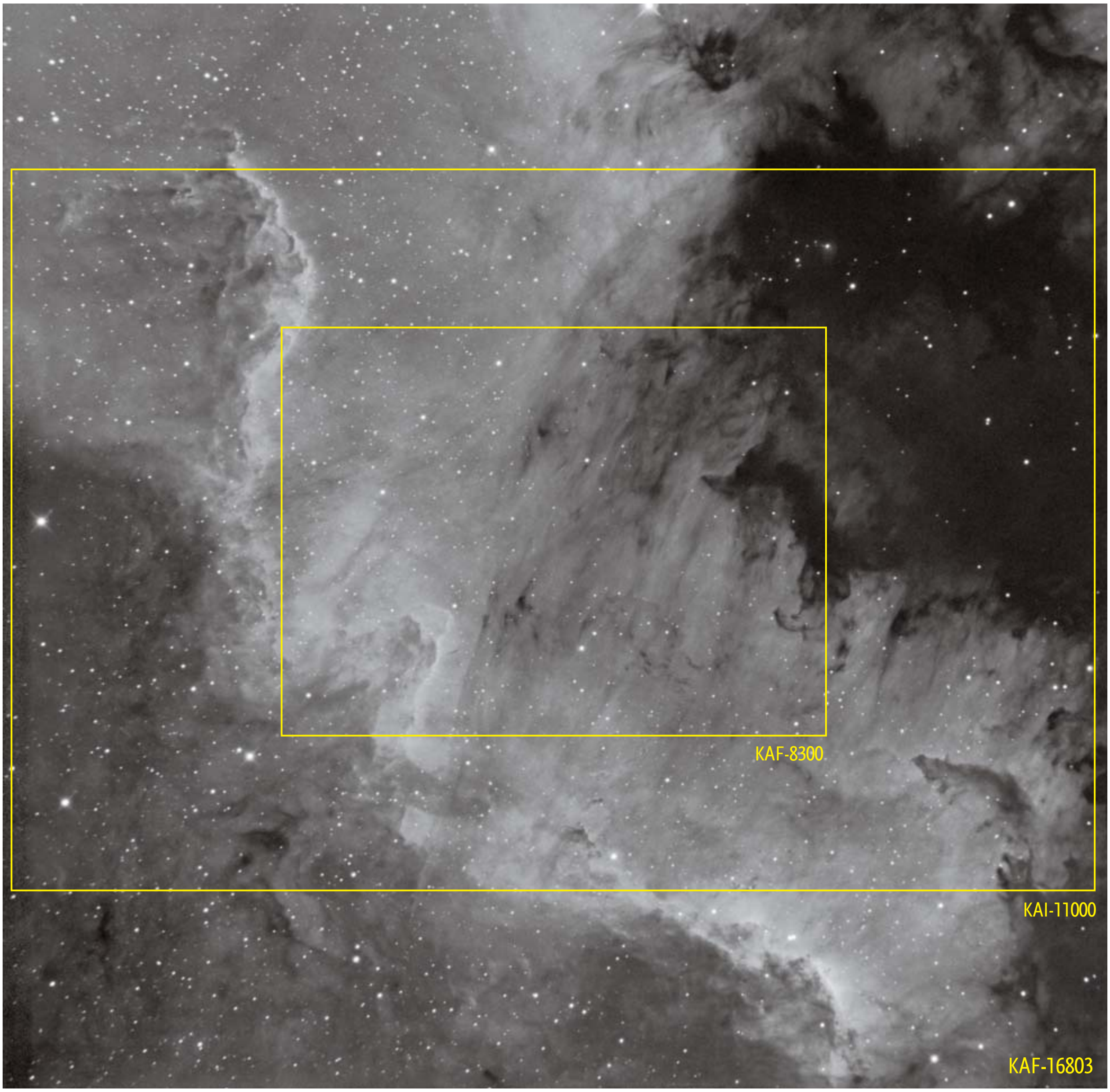
That said, there are several caveats that go with using the AT14RCT for imaging. The first involves the focuser, which is fine for visual observing and photography with relatively lightweight cameras, including most DSLRs. But the 5-pound load of my SBIG STT-8300 really pushed the focuser's limits. The friction drive often slipped, especially in cold weather. Except for the image of the North America Nebula on the facing page, I used only the focuser supplied with the scope, but on many nights it was challenging.

This, however, came as no surprise. The scope's documentation clearly states that heavy cameras will "probably require an upgrade to a rack-and-pinion focuser." Several options are spelled out, including adapters made by Feather Touch for mounting various heavy-duty focusers on the scope.

The other caveat involves an inherent aspect of RC optics. While the design is free of coma, its focal surface is curved rather than flat. In the days of emulsion-based astrophotography, photographic plates were gently bent to conform to an RC's curved focal surface. But that's not possible with digital detectors. The solution is to use a special field-flattening lens assembly mounted in front of the camera. Currently no field flattener is available for the AT14RCT. But you may not need one. For example, any image degradation due to the curved focal surface was all but invisible in my full-frame images made with the STT-8300 camera.

Larger chips will be more of a problem, especially if you're a stickler for pinpoint stars all the way to the corners of a frame. But even here there is a partial solution, and that is to focus the telescope at a point roughly halfway between the center and edge of the field rather than at the center. This slightly defocuses stars in the middle of the field while improving those at the edge. In practice this defocusing is usually invisible within the actual star images recorded by the CCD. The result is an image that *appears* uniformly focused across the frame.

I experimented with this technique when I tried several different models of large-format CCD cameras on



As explained in the text, the lack of a field flattener for the AT14RCT limits its use with large-format CCD cameras. Nevertheless, this 3-hour hydrogen-alpha exposure of the North America Nebula is a worst-case example for the KAF-16803 chip used for the exposure as well as the other CCDs indicated, since it was focused at the exact center of the field. Racking the focuser in a small amount will move the area of sharpest focus to an annular zone between the center and edge of any frame. This will improve star images at the corners of a field without noticeably affecting those at the center. The technique works for any optical system with a curved focal surface, but it is particularly effective with RC optics because they are free of coma and out-of-focus stars still appear round.

the scope. Although I couldn't get "perfect" star images all the way to the corners of a KAF-16803 CCD before those at the center appeared somewhat softened, I did get very decent results across almost all of a KAI-11000 chip (this detector is the size of a full-frame 35-mm camera). Such opinions, however, are quite subjective, so your mileage may vary.

Overall I'm very impressed with the AT14RCT. It's a great scope for visual observing as well as deep-sky photography. The lack of a field flattener limits its use with the largest CCDs, but that's not a handicap for anyone working with smaller detectors up to and including any of the highly popular KAF-8300-based cameras. And when you factor in the scope's cost, it's an outstanding value. It's a winner! ✦

Dennis di Cicco has been writing about equipment in the pages of Sky & Telescope *for more than 40 years.*

Combining Photos with DeepSkyStacker

This freeware makes stacking your deep-sky images a snap.

JERRY LODRIGUSS Among the list of important equipment required to produce pleasing images of the night sky, powerful stacking software ranks nearly as high as the camera and telescope you'll use to take your images. But with the many choices available today, which program gives you the biggest bang for your buck? Perhaps the answer is *DeepSkyStacker*, at least in the money department. The processing package won't cost you a dime and can help you produce excellent results.

DeepSkyStacker (**deepskystacker.free.fr/english/index.html**) is a PC program for CCD or DSLR imagers that provides the means to align, calibrate, and stack a series of individual deep-sky exposures into a final smooth result, ready to be stretched and sharpened in any photo-editing program.

Written by Luc Coiffier, the program is reasonably simple to use, but its many actions and settings can be daunting for beginners. It also has some surprisingly sophisticated features for more advanced users. Here I'll cover the basics to get you started.

Understanding Stacking

The universal method for deep-sky astrophotography today is to shoot a series of images of your target and then to combine (or stack) the results to produce the equivalent signal-to-noise ratio of a much longer exposure. Higher signal-to-noise ratios produce smoother images that can be "stretched" to bring out faint details in nebulae and galaxies.

Before images can be aligned and stacked, they should be calibrated first (see the April issue, p. 66). Most photo-editing programs will not perform this very important step.

A series of long-exposure deep-sky photos tends to have some unintentional, and sometimes intentional, movement between frames. Unintentional movement can come from causes like imperfect polar alignment or inaccuracies in the mount's gear train. Even with perfect tracking, having some movement between frames is often a good thing. Indeed, many experienced astrophotographers will often intentionally move the mount a little bit randomly between exposures in a process called "dithering" so that pattern noise in the sensor is averaged out in the final stacked image.

Whatever the cause, if you shoot a series of long-exposure images, the stars will most likely not line up once you stack the frames. Stellar alignment and stacking are the functions that *DeepSkyStacker* excels at.

To align a series of exposures, the program identifies reference stars common in each frame. It then shifts and rotates the individual images so they align with this reference frame. *DeepSkyStacker* then combines the aligned

STACKED Deep-sky astrophotography in this age of computers and digital cameras is easier than you might have thought. *DeepSkyStacker* allows you to calibrate, align, and stack all your images to produce smooth results with low noise that can then be processed in your favorite photo-editing software, like this image of van den Bergh 14 and 15. All photos courtesy of the author.

frames into a single result with a drastically improved signal-to-noise ratio. And this is all done automatically!

Learning the Basics

To get the most out of your data in *DeepSkyStacker,* start with reasonable-quality images that are properly exposed, focused, and tracked. The program will have trouble aligning images if they're not.

If you're shooting with a DSLR or mirrorless interchangeable lens (MIL) camera, it's important to shoot in RAW mode. It's also helpful to record your images with the correct color balance, especially if you're using filters or have a modified camera. For example, when using an unmodified camera — one that still has its factory-installed infrared-blocking filter — set the white balance to "daylight" or direct sunlight.

When shooting with a modified camera, or through light-pollution filters, you'll get your best results if you create a custom white balance by shooting a gray card illuminated by the Sun at noon on a clear day. Refer to your camera's manual to find out the specifics of how to set a custom white balance.

Exploring the Settings

The first thing you should do after opening *DeepSky-Stacker* is to go to the left-hand column in Options > Settings > Raw/FITS DDP Settings ❶. Most can be left at their defaults, though if you shoot with a DSLR or MIL, you'll need to change the settings in the RAW tab.

If you shoot RAW images with either a stock or modified camera using an appropriate white balance (daylight for stock, or a custom white balance with a modified camera or any camera with a filter), check the "Use Camera White Balance" box. When shooting with any other white balance settings, check the "Use Auto White Balance" box. Leave the "Set the black point to 0" box unchecked, even when employing bias calibration.

Note that the RAW/FITS DDP Settings apply to RAW and FITS files only; Auto White Balance will not work with JPEG images. If you did shoot in JPEG mode using daylight color balance, you can stick with the default settings. If not, you'll need to change a setting in the Light frames tab later just before stacking.

CCD imagers should select the FITS files tab. Color-camera users should check the first box and then select your camera or CCD detector from the Camera drop-down list. This setting determines the Bayer pattern used by your particular camera and is used to accurately convert the color filter array's monochrome data into an RGB color image. You'll find many other optional settings buried deep in the program, but in most cases, the defaults will work fine.

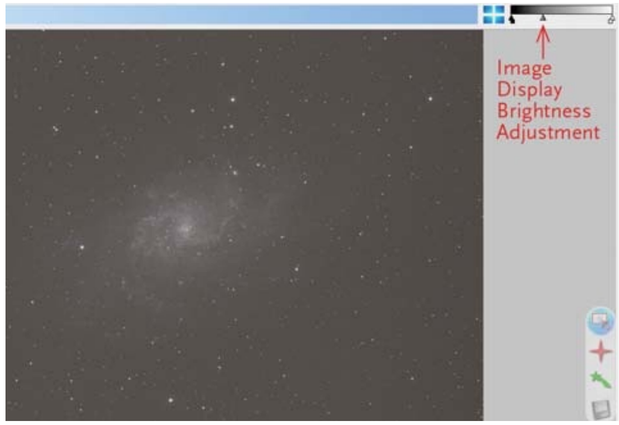
Now let's open the images. The first time you click the Open picture files command in the left column of your screen ❷, the "Open Light Frames" window appears, but you won't see any RAW-format images listed. Change the "Files of type" selection from Picture Files to All Files, and you should be able to select all your images.

Next, open your calibration files in each group ❸ by clicking the corresponding command (dark files, flat files, dark flat files, and offset/bias frames). Make sure to click "Check all" ❹ so that each group will be used when calibrating and stacking the results. The open image groups are then sorted in the bottom column of your screen, with a summary including the number in each group.

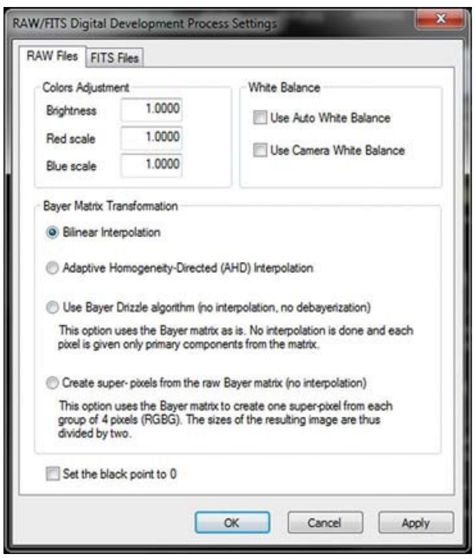
To begin processing your photos, right-click on the first image file in the list at the bottom of the screen and select "Use as reference frame." This chooses which image all the others will be aligned to, and it also opens a preview of the photo. Besides a few of the brightest stars in your photo, the image will usually appear very dark on your screen, because deep-sky targets are much fainter than the stars in a linear image. You can adjust the display using the sliders in the upper right corner of the window. Move the middle caret to the left to brighten the image. Don't worry: this adjustment only changes the display and does not actually modify the image.

Your next step is to click the "Register checked pictures" command ❺. When the action window opens, click OK to accept the default settings, and *DeepSkyStacker* will combine the best 80% of your images. You can change this to 100% if you prefer to use every image. You can also adjust the number of stars used to align the frames with the Advanced tab if the program is having trouble aligning your frames. Move the slider to the right to detect fewer stars. *DeepSkyStacker* requires a minimum of eight stars and at most a couple of dozen to work. When you're ready to move on, click OK, or cancel and click the "Stack checked pictures" command ❻.

At this point the Stacking Steps window opens, and there you can double-check all of the settings. If you shot JPEG images with a custom or incorrect color profile, select the Stacking parameters button and choose the Light tab. Now click the "Per Channel Background Calibration" line and check the box next to RGB Channels Background Calibration. If everything else is as you've

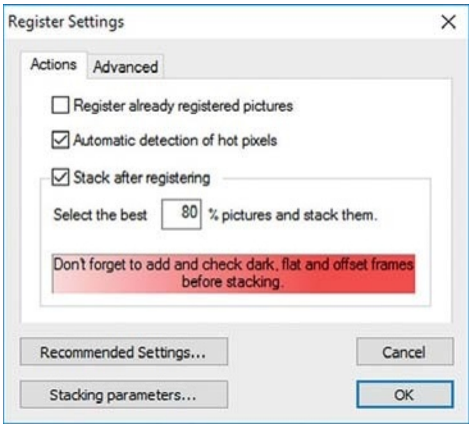


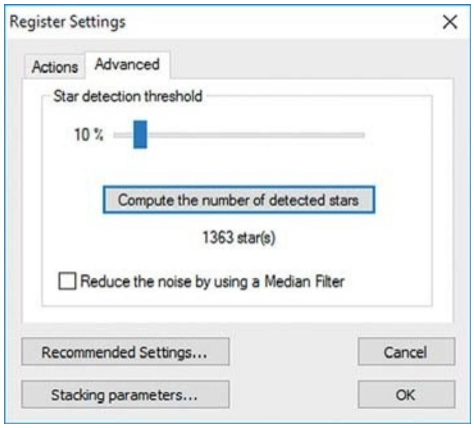
BRIGHTNESS ADJUSTMENT Most unprocessed deep-sky images appear very dark with a smattering of stars across the field. You can adjust the displayed brightness of your image by sliding the middle caret to the left. This only changes how the image is displayed and does not modify the saved photo.



COLOR SETTINGS *Above:* The first thing to do in the program is to click the Raw/FITS DDP settings and choose the correct white balance setting for how you imaged your target.

COMMAND BAR *Left: DeepSkyStacker*'s main user interface is located in a column along the left side of the screen. Important actions detailed in this article are numbered in red.





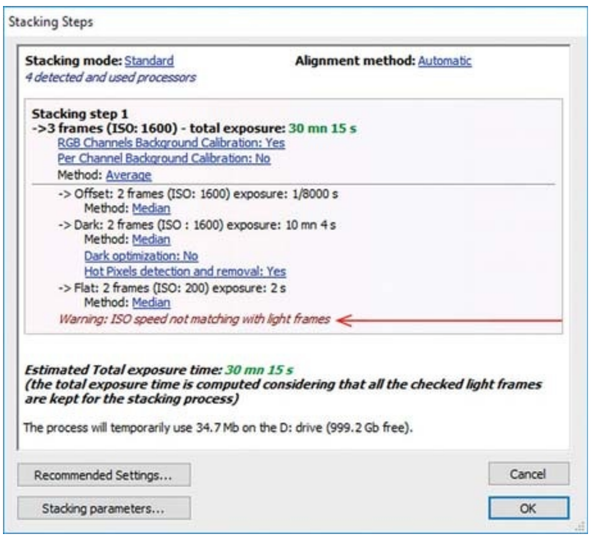
MORE OR LESS *Far left:* The Actions tab in the Register Settings window allows you to change the percentage of images used in the final stack.

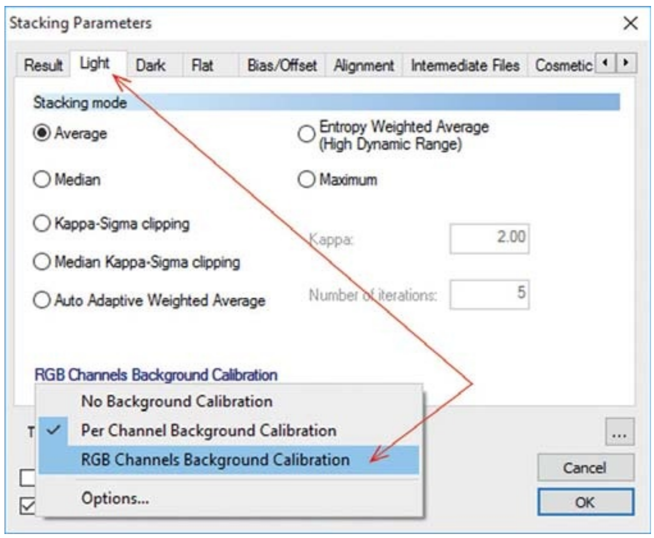
STAR DETECTION *Left:* Although the default settings often perform without issues, if your stacked result didn't properly register your images, you can adjust the number of stars *DeepSkyStacker* examines to refine its registration.

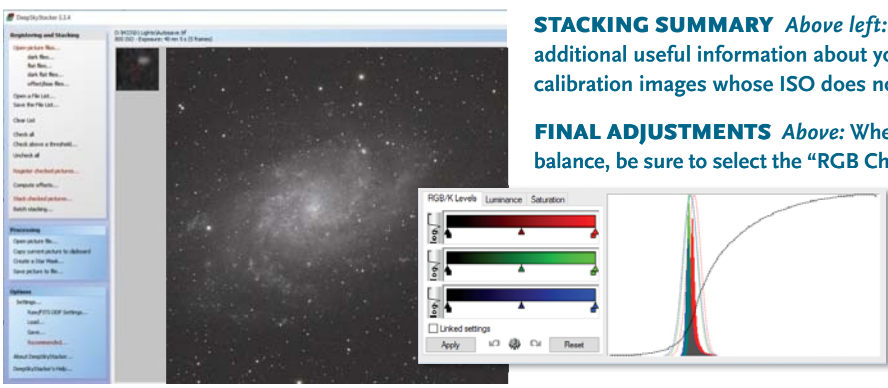
specified, click OK. The program then automatically calibrates, aligns, and stacks your images. Depending on the speed and memory of your computer, and the number of frames you're working with, this process can sometimes take quite a while, so be patient.

Once the processing is finished, the program slowly displays the stacked image. It automatically applies default adjustments for brightness, contrast, and color (if you're combining color images). These adjustments are often not ideal and might yield less than optimum results. Fortunately, as with the display adjustments mentioned earlier, the automatic settings are only applied to the display image at this point.

You can try adjusting these settings here and applying them to the image, but *DeepSkyStacker* is geared toward stacking — leave the post-processing to other photo-editing software. To save your image without applying the automatic settings, click the Save command ❼. Then a "Save As" window appears, with which you can title the file and choose the file format you prefer in your favorite editing program. Make sure you select the "Embed adjustments in the saved image file but do not



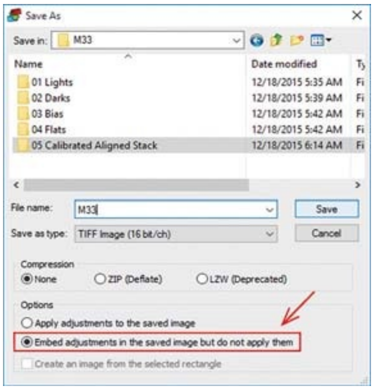




STACKING SUMMARY *Above left:* Here you can review the settings you've chosen and additional useful information about your images. Note the warning if you try to use flat frame calibration images whose ISO does not match that of the target frames.

FINAL ADJUSTMENTS *Above:* When combining JPEG images shot with an incorrect color balance, be sure to select the "RGB Channels Background Calibration" option in the Light tab of the Stacking Parameters window.

SMOOTH RESULT *Left:* When completed, the program displays the final stacked image with a series of default settings applied to the display image. Note that these adjustments are not applied to the data in the final saved file.



SAVING THE STACK Save your result as a 16-bit TIFF file with no compression, and be sure to select "Embed adjustments in the saved image but do not apply them" to get a raw linear file that can be adjusted in an another image-processing program such as *Adobe Photoshop*.

apply them" option. I prefer to save my photos as 16-bit TIFF Images with no compression. Use this option even if you've stacked JPEG images to avoid introducing compression artifacts in your final image.

Now you can open the stacked image in your favorite image-processing program such as *Adobe Photoshop* and work on it. Note that the image will appear dark at first because it has yet to be stretched to reveal faint details.

Advanced Stacking Functions

DeepSkyStacker also has many advanced settings useful for more complex stacking routines.

The program can group and manage different sets of images or exposures simultaneously. For example, it can calibrate and combine photos of the same object shot on different nights, when you might have used different exposures and have different sets of darks and flats.

After an initial set of images is loaded into the main file group tab at the bottom, you can simply load additional files by clicking on the corresponding tab before you add those additional files.

Another advanced feature in *DeepSkyStacker* is its comet stacking tools (found at the right side of the screen). The program allows you to stack a series of comet photos either by isolating the comet and removing the trailed stars, or by aligning the stars and removing the comet. Access either method by clicking the Edit Comet Mode icon and selecting the comet's location in each of your images.

Now you'll need to click the Stack checked pictures command and select the Comet tab. Here you'll click the Stars + Comet Stacking option and then hit the OK button. In a few minutes, you should have a sharp comet image against a field of well-tracked stars. The success of this method will depend on how fast the comet is moving against the star background and the length of time between exposures. See the program's help file for additional information 8.

Troubleshooting

While I've had great success with *DeepSkyStacker,* occasionally it needs some adjustments to get the best results. For some newcomers, the program appears to function, but only part of an image is displayed when it completes a stack. You might need to download the latest beta version of *DeepSkyStacker,* particularly if you're using a recently introduced camera. The beta version is actually the most recent, fully functioning program with the latest RAW decoding library.

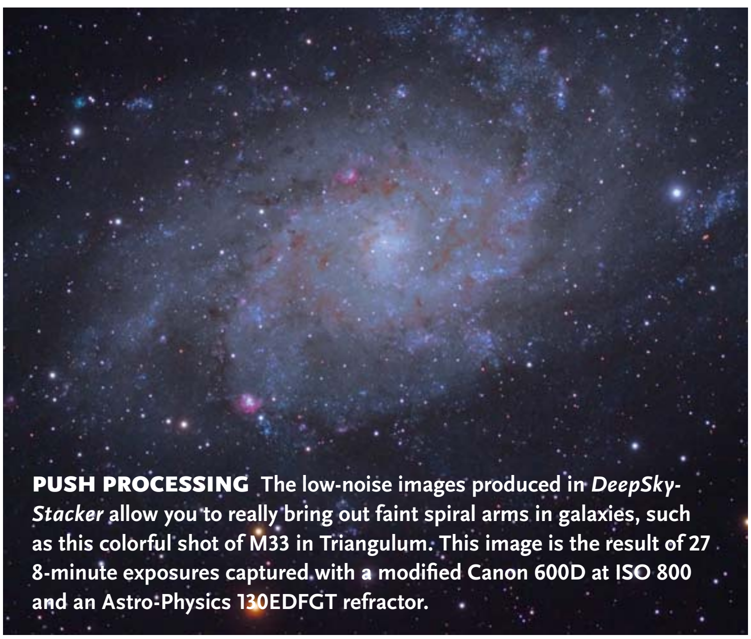
If your final stack didn't properly register and stack your images, go back to the "Register checked pictures" command and then check the "Automatic detection of hot pixels" box in the Actions tab. Also, try reducing the "Star detection threshold" in the Advanced tab.

Stacked images can sometimes display dark and light streaks, often caused by dark frames recorded at different temperatures from your light frames. These artifacts can be reduced in the Stacking Parameters window. Here you'll select the Dark tab and check both the "Hot Pixels detection and removal" and "Dark Optimization" boxes. Additionally, you may need to experiment with the "Dark Multiplication Factor" settings.

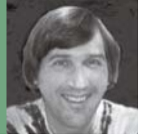
Most often, your stacked result is not as colorful as you might prefer. Don't worry — it's normal for stacked linear images to appear dark, with low contrast and little color saturation. You'll adjust all of these issues in subsequent image processing.

Overall, *DeepSkyStacker* is easy to use with some practice, and it has the ability to streamline the tedious stacking process that is necessary with most deep-sky astrophotography. Stacking is the best way to greatly increase your image quality by improving the signal-to-noise ratio, which then allows you many more processing options. ✦

Jerry Lodriguss's new book A Beginner's Guide to Astronomical Image Processing *will be out later this year.*



PUSH PROCESSING The low-noise images produced in *DeepSkyStacker* allow you to really bring out faint spiral arms in galaxies, such as this colorful shot of M33 in Triangulum. This image is the result of 27 8-minute exposures captured with a modified Canon 600D at ISO 800 and an Astro-Physics 130EDFGT refractor.



Variations In Red

Bask in the glow of a project you can build in an afternoon.

Every amateur astronomer needs a red flashlight. Red light is much less damaging to your night vision than white light (discussed last issue, page 22). Besides, that red glow looks really impressive to casual observers who might stop by to see what you're doing.

It's easy enough to make a red flashlight: just stick some taillight repair tape or Rubylith over the front of a regular flashlight. The trouble is that it's difficult to make one the perfect brightness. Worse, the perfect brightness differs depending on what you're doing. If you're reading a star chart before hunting for Stephan's Quintet, you want as little light as possible, but if you're looking for a dropped eyepiece you want enough light to glint off the barrel.

The solution is a variable-intensity red flashlight. Put some resistance between the batteries and the bulb and you can cut down the output to practically any value you want. Make that resistance adjustable and you've got a light for all occasions.

Most flashlights nowadays use light-emitting diodes (LEDs) to generate the light beam. That's a good thing, because LEDs use far less current than old-style incandescent bulbs. Your batteries last longer, and the low current draw means you can get away with something

ALL PHOTOS COURTESY OF THE AUTHOR

Two homemade variable-intensity red flashlights are seen above. They share one crucial feature: you can hold them in your mouth while flipping pages.

The contact plates separated with cardboard insulation are seen at left. Use double-sided tape to hold them centered, then feed them down the tube, while pulling the wires out as you go.

that used to be verboten: you can use a simple potentiometer as your variable resistor.

Small, dime-sized potentiometers typically can't handle more than a few dozen milliwatts before they burn out. If you hook one up to an incandescent bulb, your potentiometer won't last as long as the batteries. But LEDs pull so little current that the potentiometer doesn't overheat and can last for years.

That's assuming you use a flashlight that only lights a few LEDs. One of the most common flashlights these days is the little inch-wide, three-inch-long tubular guy that uses three AAA batteries and has nine LEDs; and that's just about the limit. I've tried them, though, and they seem to work fine. I haven't burned one out yet.

Fortunately these flashlights are cheap. Harbor Freight Tools (**harborfreight.com**) includes one free with any other purchase (like the roll of electrical tape or the soldering iron you'll need for this project) if you have a coupon. Even if you can't cadge one for free, they're only a couple bucks at most places.

So what else do you need? The potentiometer, of course. A 1-kilohm value works about right. The kind with the thumbwheel will make it easy to adjust one-handed. There are too many options available to list here; just get what you can find and adapt it to your project. (The one on the facing page is a Piher 437; their PT15 series is similar.)

Your basic goal is to interrupt the current flow between the battery and LEDs and get that current to flow through your potentiometer instead. You can do that by putting two contact plates between the battery and the spring on either end of the flashlight, with an insulator between the contact plates. It would be easiest to do that on the switch end, but that would mean moving the contact plate assembly aside every time you change batteries, so I stick mine down inside where it'll be out of the way. I run the wires out the side and attach the potentiometer to the flashlight barrel right there where I can adjust it with my thumb and forefinger while holding the light. Shoe Goo (the duct tape of glues) works well for this, but make sure you don't accidentally glue the moving parts! If your potentiometer has mounting wings like the one in the photo, you can wire it in place rather than glue it.

Reassemble the flashlight, and voila — a variable-intensity red light.

You can also make a red flashlight from scratch using a single red LED, a 10-ohm dropping resistor in a series with the 1K (or even 2K) potentiometer, and any kind of handle that will hold two or three 1.5-volt batteries. The yellow flashlight shown here started life as the handle of a battery-operated fan. The electronics are in the motor compartment. Note how I carved out a notch for the thumbwheel, but the bulk of the potentiometer stays inside the housing.

Let there be light! But remember: astronomy happens when the lights go out. ✦

Jerry Oltion sometimes uses green light just to mess with people's heads. Send him your ATM projects at ***j.oltion@sff.net****.*

The interior of a "built-from-scratch" flashlight. Two AA batteries go in the compartment on the right. One battery terminal connects to the 2K potentiometer and a 10-ohm dropping resistor. The slide switch on top connects the other battery terminal to the LED, completing the circuit.

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◀ SOUTHERN-SKY SHOWPIECE

Luiz Duczmal & Jaspal Chadha

The spectacular Carina Nebula (NGC 3372) is an active star-forming region anchored by the massive, unstable star Eta Carinae (at lower left in the bright trianglular nebulosity). To its immediate right is a dark patch called the Keyhole. **Details:** *Takahashi FSQ-106ED astrograph and Atik 383L + CCD camera used with Baader LRGB filters. Total exposure: 11.7 hours.*

◀ JUPITER SHINES ON

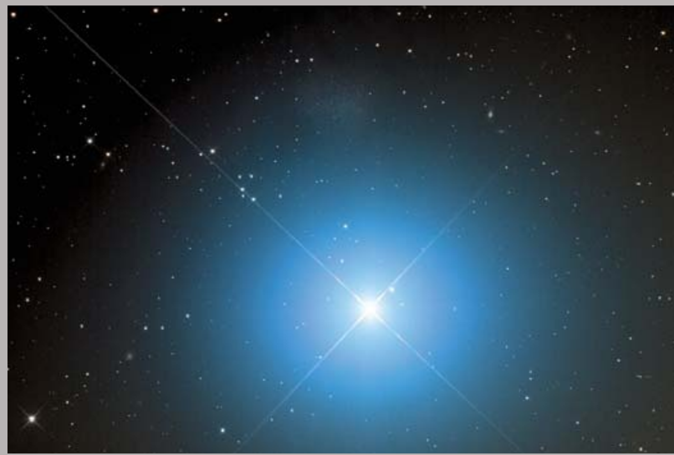
Alexei Pace

Captured on March 14th, a week after its opposition, Jupiter sports a dark North Equatorial Belt, a very turbulent South Equatorial Belt, and a distinct (but shrinking) Great Red Spot. **Details:** *Celestron EdgeHD 14 Schmidt-Cassegrain telescope with QHY5III224C CMOS color video camera. This is a stack of 42,000 individual frames.*

▼ FIRE IN THE SKY

Trisha Donajkowski

A dramatic fireball lit up the predawn sky over Joshua Tree, California, on February 20, 2016. But few in the Los Angeles area (glow at lower left) saw it. **Details:** *Sony SLT-A77V DSLR camera at ISO 1600 and 16-to-50-mm zoom lens used at 16 mm. Exposure: 13 seconds.*



▸ HIDING IN PLAIN SIGHT

Gregg Ruppel

Ignore the dazzling glare from Regulus and look just above it to spot the soft glow of Leo 1 (UGC 5470), a dwarf spheroidal galaxy located 820,000 light-years away. Eyeing this challenging, 11th-magnitude object requires a moderately large-aperture telescope and dark skies. **Details:** *ASA 10N astrograph with SBIG STL-11000M CCD camera and Astrodon filters. Total exposure: 5½ hours.*

TANGLED NEBULOSITY

Kfir Simon

IC 4603, a dust-choked nebula in southernmost Ophiuchus, lies just 2° north of Antares. Its reflected blue light comes from 8th-magnitude SAO 184376, the brighter of the two stars at right. The dark wreath at center is designated L 1681. ✦

Details: *16-inch Dream Astrograph and Apogee Alta U16M CCD camera using Hα and LRGB filters. Total exposure: 2½ hours.*

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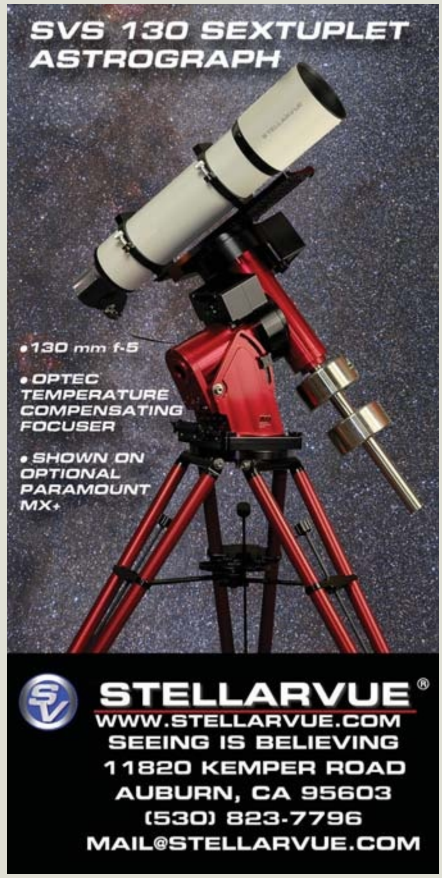

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Making It Special

Or, how to win over a crowd of eager observers when there's nothing to see

There I was, standing with my scope on a floodlit soccer field, faced with a line of hundreds of people. None of the usual great objects — the Moon, Jupiter, Saturn — that I like to impress the public with were visible. What was I going to do?

The event was part of Israeli Space Week, held annually to commemorate Ilan Ramon, Israel's first astronaut. Ramon was part of the STS-107 crew lost in the Space Shuttle *Columbia* disaster in 2003.

Months before, the organizers had given me the dates I'd show off the heavens. I'd quickly determined that little of interest would be visible when most of the kids and their parents would be lining up. I recommended canceling so as not to disappoint attendees, but the organizers were obligated.

When I arrived in the coastal town of Nahariya on February 3rd, the sky looked clear, and I felt confident. The night before, in the town of Karmiel, I had successfully displayed the Orion Nebula and the young stars in the Trapezium to several hundred enthusiastic spectators.

But in Nahariya the organizers had me set up my telescope beneath two large floodlights. Officials rejected my request to turn the lights off, supposedly for security. All I could distinguish through the blazing light pollution was three stars: Rigel and Betelgeuse in Orion, and Sirius, which, though brightest, was still too low for observation.

The queue was lengthening by the minute. What to do?

Fortunately, as I was aligning the finder, an idea popped into mind: I would aim the telescope at one of those bright stars. The image would not be special — I would have to make it so. I would have to transform any feelings people might have of "I waited all that time for *this*?" into "Wow, that's so cool."

A boy looks at Rigel through the author's homebuilt scope on February 3, 2016.

EDEN ORION

So I pointed the telescope at Rigel and informed visitors that they were looking at one of the ten brightest stars in the sky. That it was a type of star known as a blue-white supergiant. That it was much hotter, tens of times larger, and tens of *thousands* of times brighter than our Sun. That it emitted the light they were seeing more than 800 years ago, and its photons had traveled more than 5 quadrillion miles to arrive straight to the eyes of each and everyone in line at Nahariya.

I told this story hundreds of times that evening. I shared it with girls and boys, mothers and fathers, all of whom had waited in the cold to see the star shining in the eyepiece especially for them. Not all "bought" the story, but many did, and those that did hurried to tell others what they had witnessed: "Mom, I just saw a star whose light traveled hundreds of years just for me!"

Providing this personal meaning to every child (and parent) who peered through the telescope and established that cosmic connection, made this observation one of the best I've ever experienced. Enthusiasm and wonder are contagious. Successful public outreach depends more on you than on what you've put in the eyepiece. ✦

***Eden Orion**, an artist and webmaster for the University of Haifa, lives in Qoranit, Israel. An avid amateur astronomer, he enjoys organizing star parties, telescope-making sessions, and other astronomy-related activities for the public.*


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