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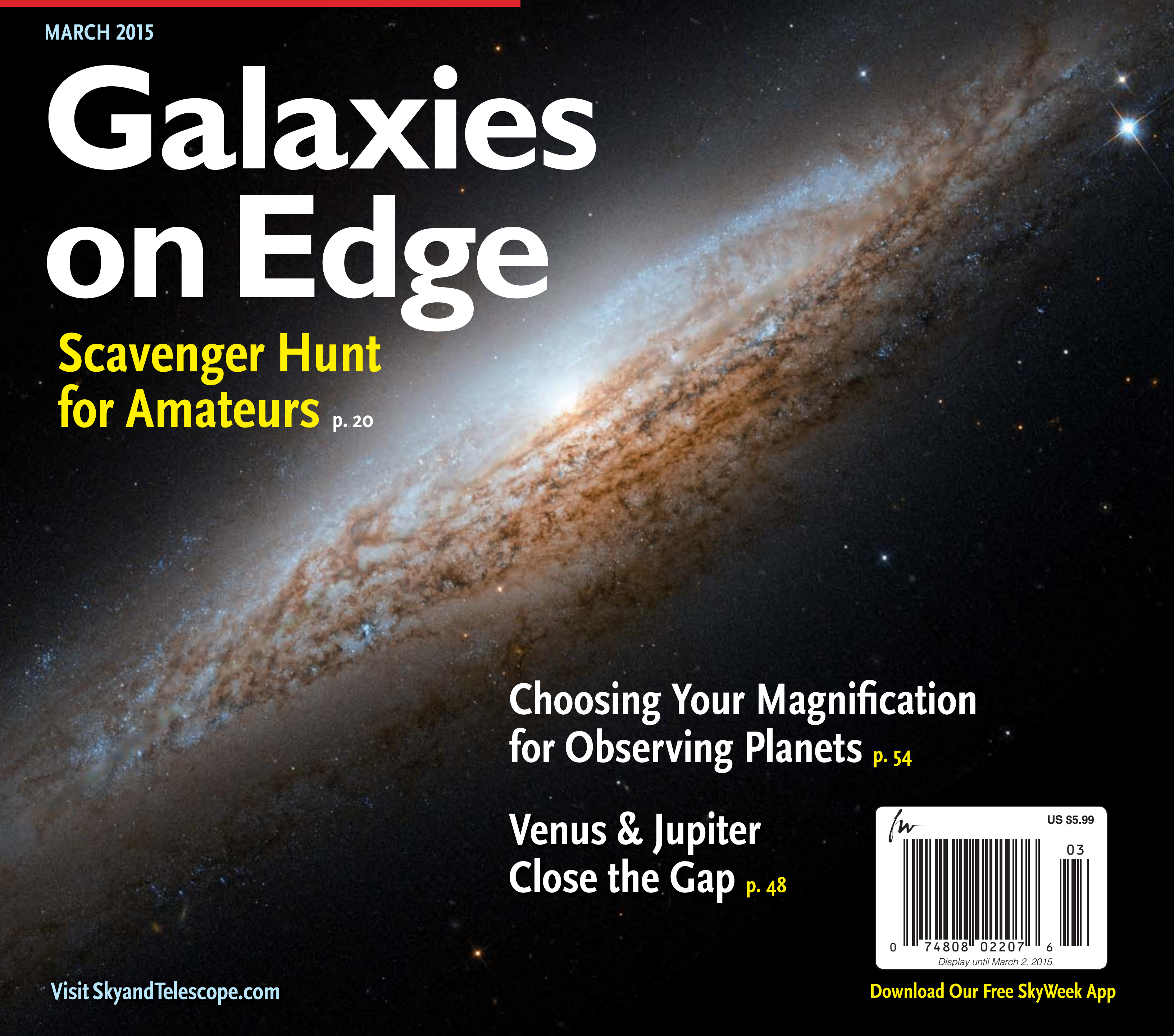
THE ESSENTIAL GUIDE TO ASTRONOMY

SKY & TELESCOPE



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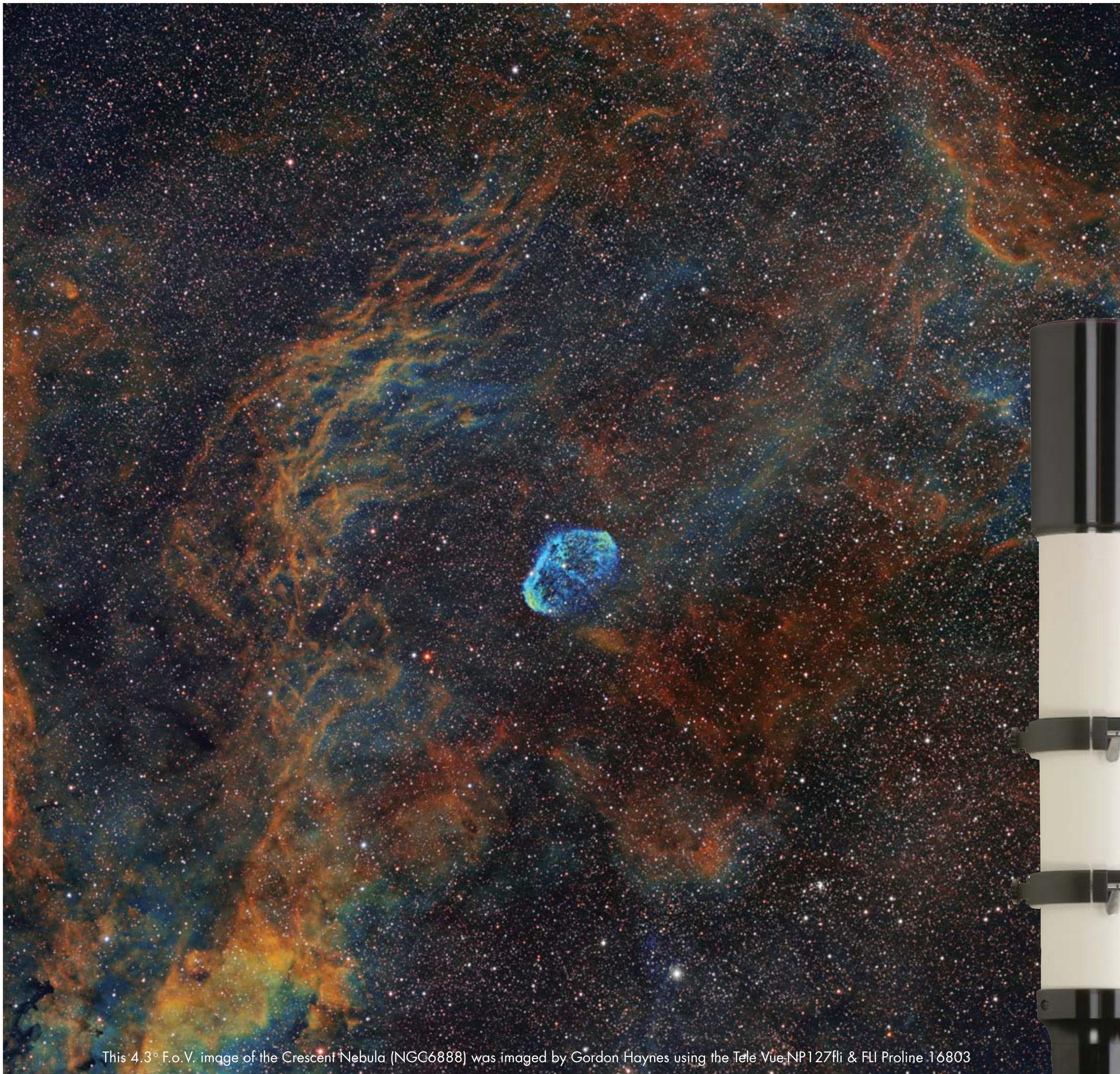
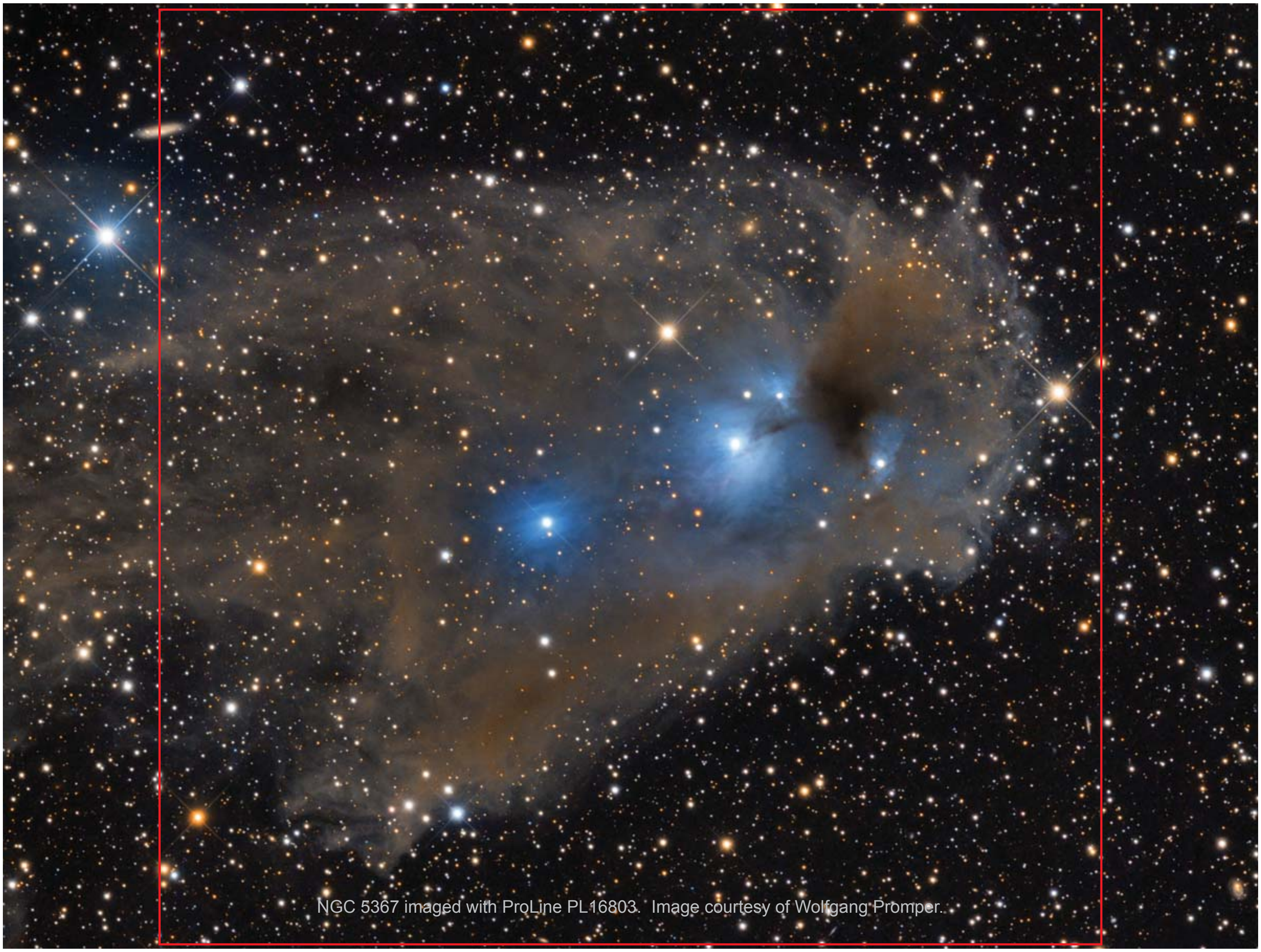


This 4.3° F.o.V. image of the Crescent Nebula (NGC6888) was imaged by Gordon Haynes using the Tele Vue-NP127fli & FLI Proline 16803



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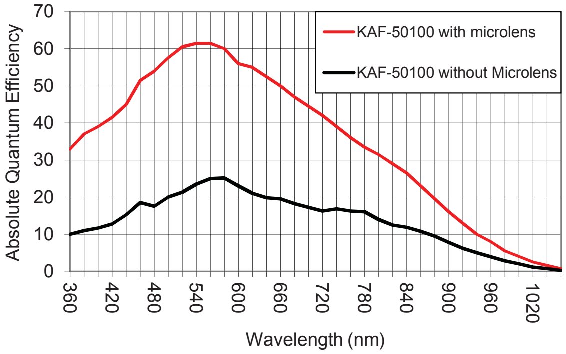

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March 2015 VOL. 129, NO. 3

On the cover:
The barred spiral NGC 2683 is one example of the iconic (and sometimes challenging) edge-on spirals.

PHOTO: ESA / NASA

FEATURES

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OBSERVING MARCH

S&T TEST REPORT

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March 2015 Digital Extra

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- **Explore Vesta**
  View Dawn's high-res map of the asteroid it circled for more than a year.
- **Mutual Events Among Jupiter's Moons**
  Jovian moons are eclipsing and occulting each other – find out how to watch.

Photo Gallery

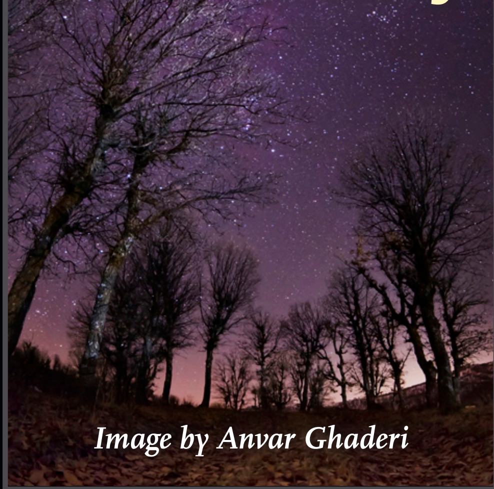

Image by Anvar Ghaderi

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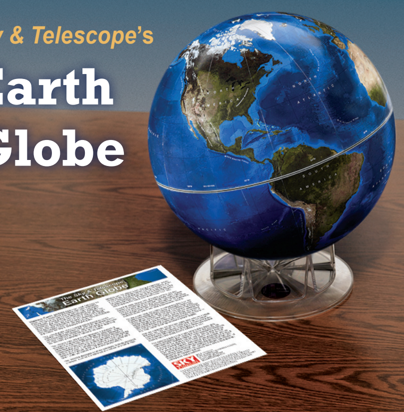

DIGITAL BACK ISSUES:
December, January, and February

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ONLINE PHOTO GALLERY
José J. Chambó Bris captured Comet C/2014 Q2 (Lovejoy) in November 2014 as it was nearing 8th magnitude.

Peter Tyson
Spectrum

Ageless Wonders

I HAVE A PIECE OF AMBER with a cricket in it. It's an ordinary cricket, just like one you'd find in your backyard: bulging eyes, sweeping antennae, those absurd jutting legs. If I caught sight of one of its kind springing through the grass at my feet, I wouldn't think twice about it. And sometimes I don't think twice about this particular cricket, because it's just one fossil insect of many in the pieces of amber I own.

But if I pause to consider what this humble bug really is, a mini nova of awe and fascination erupts in my mind. This cricket is roughly *20 million years old*. When it leapt its last, maybe to avoid a predator, it landed in a blob of sticky resin oozing down an algarrobo tree in what is now the Dominican Republic. It has been entombed just so ever since.

PETER TYSON

KEN CRAWFORD

The cricket is perfectly preserved, as if it jumped just a second ago. Through the eyepieces of my stereomicroscope, I can even see tiny hairs on its legs and color markings on its retracted wings. This is the *actual* animal, not a compression fossil like a fern on slate. If our science had advanced far enough, what could this long-extinct creature reveal about its evolution, biogeography, primeval ecology? What if I could turn the clock back to the exact moment of its interment? What would I see around me? Hear? *Smell*, eons before air pollution?

In "Edge-on Galaxies" (page 20), Ted Forte exhorts us not to take the astral marvels he describes for granted, as I've sometimes done with my cricket. "It's so easy to get lost in the mechanics of detecting these faint patches of light that we might lose sight of the real significance of what it is we're capturing," he writes. "I urge you not to let that happen."

Remind yourself, as you resolve yet another glowing disk in your eyepiece: This is a galaxy! It boasts untold billions of stars and planets. It is almost inconceivably vast. Its light departed millions of years ago, yet the galaxy is still out there somewhere. Extraordinary things are surely happening there *right now*: stars exploding, planets forming, possibly organisms like my cricket — or totally unlike my cricket — going about their lives amidst that distant disk of light and dust.

It's worth pinching ourselves. As Forte says — and the same could be said of my cricket — "Galaxies may be viewed through the eyepiece, but they're appreciated through the imagination."

Peter
Editor in Chief

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The Essential Guide to Astronomy

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GOTO

Largest (and best!) in Indiana

In October, Ball State University in Muncie, Indiana, opened the Charles W. Brown Planetarium - the largest in the state. After operating a 30' dome for more than 30 years, Dr. Ron Kaitchuck moved into a totally new 52' dome featuring a GOTO INC CHRONOS II HYBRID system with fulldome video by RSA Cosmos. Prime equipment contractor Ash Enterprises helped to design the dome with 148 seats, great handicapped accessibility, and ample space for lectures or small ensemble concerts.

A vibrant undergraduate program at Ball State reaches more than 1,600 astronomy students each year – one of the largest enrollments in the country! In addition to this large and growing number of university students, the new planetarium will also serve area K-12 school children and the surrounding community, continuing Ball State's 47-year tradition of providing all planetarium programs free of charge.

At the center of the action is the new GOTO CHRONOS II totally LED-illuminated opto-mechanical star projector. It is getting rave reviews from astronomy faculty, amateur astronomers, and fellow planetarians who gathered for a Great Lakes regional conference in the dome one week after its dedication. The CHRONOS II's 8,500 stars, combined with the 10,000,000 micro-stars which make up the Milky Way and deep sky objects are simply amazing. It is so realistic that the staff delights in loaning binoculars to visitors to show them the sky as it has never before been seen in a planetarium.

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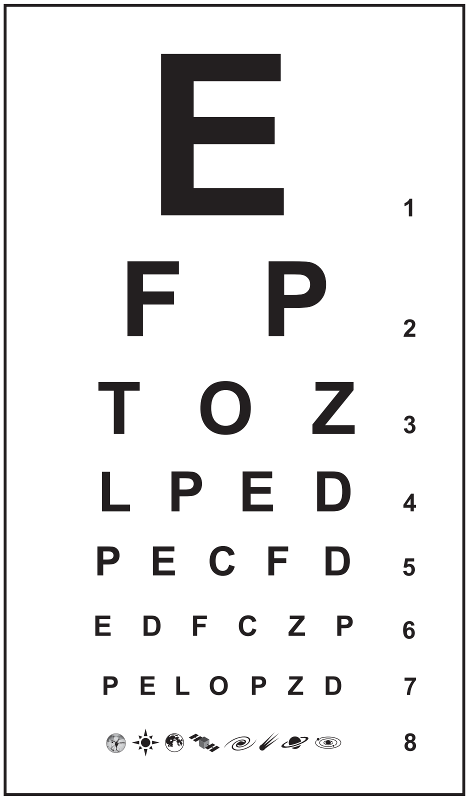

Cataract Surgery: Wows and Woes

Thanks for going out of your way to educate your readers on the latest in medical advances important to astronomers! Kathy and Jerry Oltion's article on cataract surgery, secondary cataracts, and the follow-up capsulotomy (*S&T*: Sept. 2014, p. 34) was just in time for me. My surgery was scheduled for the same week that the September issue arrived in my mailbox, and I faxed the article to my surgeon. Not only did he read the article, he said some of it was new to him as well, and he has saved it in his own files for future reference.

My surgery went perfectly, thanks to your continued dedication to your readers and a terrific doctor open to suggestions from his patients. I celebrated by buying a new and (of course) larger Meade telescope — and the universe awaits! Thank you!

Linda Huffman
Squaw Valley, California

I found "Clearing the Clouds: Cataract Surgery for Astronomers" well-written and highly informative. I, too, had cataract surgery in both eyes and at first experienced diffraction spikes around streetlights, porch lamps, and almost every bright object in my telescope. The bottom illustration of Saturn on page 36 of the article is very much like what I saw. I brought this to my surgeon's attention; he said to wait a few days for the new lens to settle. Sure enough, it did so on its own, and I needed no more surgery. For new cataract patients, if you do experience artifacts right after surgery, you might want to wait a while before going under the knife again, just to make sure the effects are not temporary.

Omar Zuhdi
Shawnee, Oklahoma

I enjoyed reading about the Oltions' experience with cataract surgery. I also had the surgery in both of my eyes in April and May of 2013, when I was 77 years old. Prior to the surgery, when I looked at the bright star Sirius I saw about six images of the star, plus about eight diffraction spikes.

One of the first things I noticed after the surgery on the first eye was how much bluer things appeared. Before surgery, I checked the color response of my vision with a handheld spectroscope and found that I saw a normal bell-shaped color range of about 420 to 710 nanometers. After the surgery my color range was about 395 to 720 nm. The violet cutoff is sharp; apparently there is a UV cutoff in the replacement lenses. But I can now see the H and K calcium lines! My former uncorrected vision was 20/30 with glasses; now it's 20/15, which is better than the normal response. I think I must have gained a full magnitude in the stars I can see.

I still wear glasses to correct for my astigmatism, as I opted not to have Toric lenses implanted to correct it. I have had none of the diffraction spikes Ms. Oltion experienced. It is delightful to again enjoy the sky as I did many years ago.

Aaron Martin
Browns Summit, North Carolina

I was considerably interested in the Oltions' article, since I had the same surgery in May 2013. I'm sad to say my situation did not work out as well as Ms. Oltion's did. I was attracted to the option of a multi-focus lens and interviewed one of the clinic staff members who had them, who assured me that everything worked fine. But after the first eye surgery there were huge diffraction circles around any bright point of light, such as bright stars and headlights. My surgeon assured me that it was a temporary effect and talked me into having the second eye surgery the next week, so both eyes saw every bright thing circled with concentric rings of light. The condition persisted even after I had a capsulotomy, and even now distant car headlights are ringed at night and a fuzz surrounds the Moon. The surgeon finally admitted that the diffraction rings are necessary for the lenses to work correctly. So I'm stuck with them. Until eye specialists iron the bugs out of these lenses, I wouldn't recommend them to any serious visual astronomer.

Terry Herlihy
Chicago, Illinois

I underwent bilateral cataract surgery a couple of months before the Oltions' article came out, but I did not develop the diffraction spikes that Ms. Oltion did. I did initially develop spherical aberration, though, resulting in halos around very bright streetlights. Over the course of several months the haloing effect faded, and these days I don't see halos much at all with stars.

For now, I wear progressive bifocals most of the time to achieve maximum depth of field, and I use a variety of magnifiers and wide-diameter reading glasses for close-up viewing and reading. My eyesight has continued to change as the months progress; one eye is now nearsighted and the other farsighted. But even without glasses, my color vision and overall vision

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are much better than prior to the surgery.

The lesson of course is that each person's post-surgery experience will be somewhat different. And although the procedure will improve, it will not necessarily provide perfect sight. We'll likely continue to tweak our vision with external appliances or even additional surgeries to make further refinements.

Dr. Kenneth Lum
San Carlos, California

What happens to our vision after eye surgery in which the lens is removed and there is no lens implant? At 17 years old I was struck in my right eye by a hard-hit baseball. Internal bleeding and a period of blindness ensued; a few years later a surgeon removed my lens as part of a clean-up procedure, because the lens had become a severe cataract. The only implant was a plastic buckle, inserted to keep my retina in place. Since then I have worn a contact lens along with my glasses to see clearly with that eye.

During this time I was already bitten by the astronomy bug. But although I cursed the injury's effects on my daily life, it had some positive effects on my observing. When I removed the contact lens and looked through the telescope with my damaged right eye, I could see fainter stars than with my good eye. On May 4, 1994, I finally put this discrepancy to the test. Using a chart of M3 in the book *Observing Handbook and Catalogue of Deep-Sky Objects* by Luginbuhl and Skiff and an 8-inch SCT, I determined that I could see stars to magnitude 13.9 with my left eye, but at least to 15.1 with my right eye!

Another interesting effect is on star colors. Blue stars appear violet. It makes colorful doubles such as Albireo all the more dazzling.

The only two negatives are a small, oval-shaped blind spot near the center of my vision where detail is lost, and in 2007 a posterior vitreous detachment (PVD), a pulling away from the retina of the clear substance inside the eye. PVDs are common in aging eyes but also happen after injuries and surgeries. In my case, the PVD produced flashes of light and a large mass of floaters. As time has gone by this mass has become nearly transparent, but it still gives me some difficulties at the telescope.

Stan Howerton
Arkansas City, Kansas

For the Record

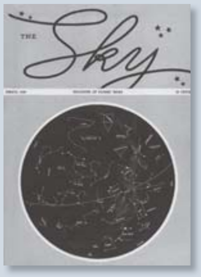
✷ *The November 2014 Going Deep column (p. 60) inverted IC 1504 as IC 5014 in the text; the label in the finder chart is correct. And to continue our number-inversion trend, the label for Espin 38 in the December 2014 Deep-Sky Wonders chart (p. 56) incorrectly said Espin 83; the column's text is correct.*

✷ *The Test Report in the December 2014 issue (p. 66) incorrectly stated that the Edge 800 SCT and VX mount sell together for $1,799. Celestron sells the combo for $1,999.*

✷ *The News Note on the Laniakea Supercluster (*S&T*: Dec. 2014, p. 16) incorrectly converted the recessional velocity of 10,000 km/s to a distance of 130 million light-years; it's 130 million* parsecs *(1 parsec = 3.26 light-years). So the distance is roughly 400 million light-years.*

75, 50 & 25 Years Ago

Roger W. Sinnott



March 1940

Southern Lights "For the first time in New Zealand, and possibly for the first time in the world, the prediction of the occurrence of an aurora was made with certainty on August 22, 1939. . . . The director of [Carter Observatory], Mr. M. Geddes, noticed in the case of a number of aurorae that the earth currents which accompanied the displays and seriously interfered with telephonic and telegraphic communication frequently began on the afternoon preceding the auroral display. Arrangements were consequently made with the post office for prompt advice of such interference, and when earth currents became evident on the afternoon of August 22nd last it was possible to warn the photographic stations . . . of the brilliant aurora which became visible when darkness fell."

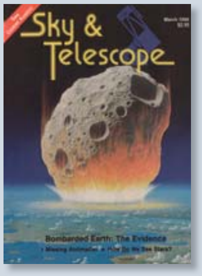
R. A. McIntosh made no mention of solar activity, long suspected but not yet shown to play a role in the aurora. That connection was finally established in 1948.

March 1965

Is Pluto Big? "Combining old and new photometric data, [Robert Hardie of Dominion Observatory] has determined [Pluto's] synodic period of rotation with 10 times the previous accuracy; it is 6.38673 days. . . . The shape of Pluto's light curve is now known with considerable confidence [and], reasons Dr. Hardie, Pluto's disk is brightest at its center and darkened toward its rim.

"As a result, Pluto must be larger than hitherto believed, by an as yet unknown amount. The diameter that G. P. Kuiper determined, 5,800 kilometers, evidently refers to the central bright spot, not the entire disk."

Estimates of Pluto's size varied wildly in the half century after its 1930 discovery. Then in the 1980s a series of mutual occultations of Pluto and its main moon, Charon, clarified the picture. Astronomers now estimate that Pluto's diameter is only about 2,300 km, half that of Mercury and two-thirds that of the Moon.



March 1990

Where's the Antimatter? "[T]here should exist antiprotons and antineutrons as well as antielectrons, which are still called by their original name of positrons. . . . After World War II antiprotons and antineutrons were discovered in cosmic-ray experiments. . . .

"[A key] discovery would be that of a nucleus of some heavier antielement such as helium [with] two antiprotons and two antineutrons. There is no way that this complicated structure could be created by a high-energy collision [on Earth]. If even a single nucleus of antihelium were discovered it would strongly suggest the existence of antistars."

Notwithstanding Paul Davies' review article, a few particles of antihelium were created, if fleetingly, at the Brookhaven National Laboratory in New York in 2011. That same year the multinational Alpha Magnetic Spectrometer (AMS-02) was delivered to the International Space Station, where it continues the search for primordial antihelium.

MISSIONS I Hayabusa 2 Is Asteroid Bound


AKIHIRO IKESHITA / JAXA

The Japanese Hayabusa 2 mission will travel to asteroid 1999 JU$_3$ with a host of instruments, to take samples and bring them back to Earth.

On December 3rd, the Japan Aerospace Exploration Agency (JAXA) launched the spacecraft Hayabusa 2 on an epic journey — to an asteroid and back again. The intrepid asteroid explorer will rendezvous with near-Earth asteroid 1999 JU$_3$ in 2018 and obtain samples from its surface before returning to Earth in 2020.

Hayabusa 2 is the successor to the first Hayabusa mission, which is so far the only mission to bring samples of an asteroid back to Earth. Hayabusa 1 limped home with particles from iron-rich 25143 Itokawa in June 2010 (*S&T*: Sept. 2010, p. 18).

Hayabusa 2's target asteroid, 1999 JU$_3$, is an Apollo asteroid roughly 900 meters (3,000 feet) in diameter with a period of 7½ hours. It generally circles the Sun between the orbits of Earth and Mars and is a C-type, or carbonaceous, asteroid. C-type asteroids are the most common type of asteroid, dark gray, and often seen in the main asteroid belt's outer regions. They are thought to contain significant quantities of water and organic compounds, and many scientists think Earth's water was brought here by similar carbonaceous fragments bombarding our primordial planet. Because asteroids formed early in the evolution of the solar system and have changed little since then, 1999 JU$_3$ and its kin might hold tantalizing clues from this era.

Similar in design to its predecessor, the main body of Hayabusa 2 is 1 meter × 1.6 meter × 1.4 meter. It weighs in at a total of 600 kg (1,300 lbs), including fuel. When extended, its solar panels span 6 meters.

One new feature is a speeding bullet: the spacecraft's Small Carry-on Impactor will use an explosive device to shoot a 2-kg copper projectile at the asteroid at a velocity of 2 km/sec (4,000 mph). The spacecraft will deploy a camera to watch the impact (the craft itself will hide behind the asteroid), then return to sample the debris in order to study pristine material from beneath the asteroid's surface.

In addition to taking samples during brief touchdowns in several locations on the asteroid's surface, Hayabusa 2 will also study 1999 JU$_3$ remotely, using its near-infrared spectrometer and thermal infrared imager to examine the temperature variations and mineral composition of the asteroid. Hayabusa 2 will also bring along several traveling companions to make close-up observations: three small Minerva-II rovers (similar to the failed Minerva from Hayabusa 1) and the German Mascot lander.

■ **EMILY CONOVER**

GALAXIES I Dark Galaxies Discovered in Coma Cluster

A bizarre set of galaxies in the Coma Cluster have lost most of their stellar material, making them especially rich in dark matter.

Pieter van Dokkum (Yale) and colleagues found the galaxies when they took a unique look at Coma through the Dragonfly Telephoto Array, a group of (then) 8 Canon telephoto lenses coupled to CCD cameras on a single mount. The 47 galaxies lurk on the cluster's outskirts and are similar in size to the Milky Way — but with 1⁄1,000 the number of stars.

To survive in Coma's gravitational turmoil, these dark galaxies must contain 98% dark matter to hold themselves together, much higher than the fraction of matter in the universe at large (83%). Either these weirdly faint galaxies have lost their stars, or they never had many stars in the first place, the team reports October 29th on the open-access site arXiv.org.

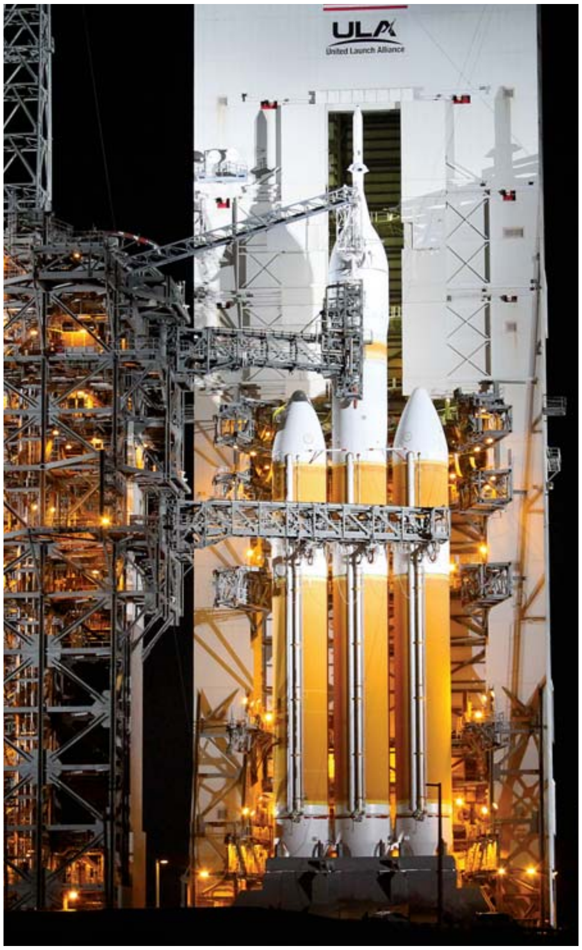
Van Dokkum and colleagues suggest that these may be "failed" galaxies, having forfeited most of their star-building gas after hosting a first generation of stars.

Stars in dwarf galaxies can delay subsequent stellar generations by heating and expelling gas (*S&T*: May 2014, p. 12). But simulations also suggest that even normal galaxies start out with three times more star-building material than they use. The energy supernovae dump into their surroundings is one way to limit star formation, says Greg Stinson (Max Planck Institute for Astronomy, Germany).

"I was actually very much relieved to see Prof. van Dokkum's paper," he adds. Dark matter simulations have been producing galaxies with exactly the size and matter distribution that van Dokkum's team observed, but such galaxies are naturally difficult to observe.

■ **MONICA YOUNG**

MISSIONS | Test Flight Success for Orion Spacecraft . . .



HAP GRIFFIN

NASA's Orion capsule launched on December 5th after a day's delay. The capsule sits just beneath the needle-like launch abort system at the top of the flight assembly.

On December 5th, NASA successfully launched its Orion capsule. The spacecraft lifted off at 7:05 a.m. EST (12:05 Universal Time) from the Kennedy Space Center aboard a Delta IV Heavy rocket, did two orbits, and then landed safely in the Pacific Ocean 4½ hours later without mishap.

NASA intends Orion to be the next generation in manned spaceflight, although this flight wasn't manned. Scheduled to carry astronauts beyond low-Earth orbit in the 2020s, the spacecraft will be NASA's first deep-space people transporter since the Apollo days.

The flight tested several aspects of the Orion system. For example, modern computers are more susceptible to radiation than their 1960s counterparts, and the NASA–Lockheed Martin team wanted to see how they'd fare passing through the Van Allen belts. (The computers were shut off for 15 minutes during up and back passes and emerged unscathed both times.)

Orion first inserted into a low-Earth orbit about 17 minutes after launch, reaching an altitude on par with that of the International Space Station. Then 2 hours after launch the second stage reignited, pushing Orion out into its higher orbit. The craft reached an altitude of 5,800 km (3,604 miles), 15 times farther out than the ISS orbits, before coming back to Earth.

This second orbit was crucial for testing the heat shield. The spacecraft's 5.03-meter-wide (16.5-foot-wide) heat shield is the largest yet made. Orion needs the under-development Space Launch System (SLS) to reach the Moon, but its reentry speed on the test flight still reached about 9 km/s (20,000 mph), 84% of the reentry speed it would have if returning from a lunar mission. This blazing arrival heated the shield to 2,200°C (4,000°F); the shield's composite material, called Avcoat, can withstand 3,300°C and showed no problems during reentry.

The next launch is slated for 2018. That mission, Exploration Mission 1 (EM-1), will circle the Moon but also won't carry people. Due to budget constraints, the crew systems won't be in place; EM-1 will also be the first-ever flight of the SLS system, and mission planners don't want to risk lives on untested technology. If all goes according to plan, the first manned mission will come in 2021.

■ **CAMILLE M. CARLISLE**

. . . and Chinese Chang'e Craft Loops the Moon

An 8-day flight for the Chang'e 5-T1 capsule ended successfully when it parachuted to safety in the Chinese province of Inner Mongolia. Chang'e 5-T1 rode a rocket to space on October 23rd and swung around the lunar farside about 13,000 km above the Moon's surface before heading back home. Apart from successfully making the round-trip lunar voyage — the first since the Soviet Union's Luna 24 did so in 1976 — the spacecraft was an engineering test for the upcoming Chang'e 5 sample-return mission. Chang'e 5 is designed to return some 2 kg (4½ pounds) of lunar material and could occur as early as 2017. This launch only tested reaching the Moon and reentry. It also recorded this view of the Moon (with Earth in the background) on October 28th. The small, dark patch near lunar center is Mare Moscoviense, one of the few lava plains on the Moon's farside.

■ **J. KELLY BEATTY**

CHINESE NATIONAL SPACE ADMINISTRATION / XINHUANET

MISSIONS | Contact Lost with Stereo B Spacecraft

Despite rescue efforts, no one has heard from one of NASA's Stereo (Solar Terrestrial Relations Observatory) spacecraft since October. The Stereo spacecraft circle the Sun in orbits similar to Earth's, with Stereo A "ahead" of Earth in its orbit and Stereo B "behind." The duo thereby watch our star's activity from angles we can't observe. Both craft have currently drifted behind the Sun, meaning that their radio antennas must point near the Sun to communicate with Earth. To protect the equipment from overheating, mission controllers decided to point both craft away from the Sun (and Earth) and to put them in safe-mode hibernation for about a year until they drifted to safety.

Stereo A successfully began its "time out" on August 20th. A month later engineers were completing Stereo B's final tests, which involved commanding the craft to go into safe mode and then resume normal operations. But there's been no radio contact with Stereo B since October 1st, the day it was supposed to wake up. Its radio signal came in weakly and then quickly faded away.

It appears that the spacecraft suffered a double whammy: first the star tracker could not lock onto its correct guide stars, and then a laser gyro in Stereo B's Inertial Measurement Unit, which senses the craft's orientation, failed and started providing bad data to the attitude-control system. There's now no way to know exactly where Stereo B is pointed or the state of its systems.

Attempts to detect the spacecraft's radio signal using the 100-meter-wide Green Bank Telescope and the 70-meter dishes of NASA's Deep Space Network have thus far failed. According to project scientist Joseph Gurman (NASA Goddard), simulations are under way to deduce the spacecraft's attitude and roll rate based on the few final bits of telemetry received.

All hope is not lost. In 1998, the Solar and Heliospheric Observatory (SOHO) also went AWOL, putting itself in a slow spin with its solar-cell arrays pointed away from the Sun. Eventually, orbital geometry provided enough sunlight (and therefore electricity) to power the craft, and mission controllers regained control. Today, SOHO still provides daily solar images.

■ **J. KELLY BEATTY**

SOLAR SYSTEM | Vesta's Geologic History

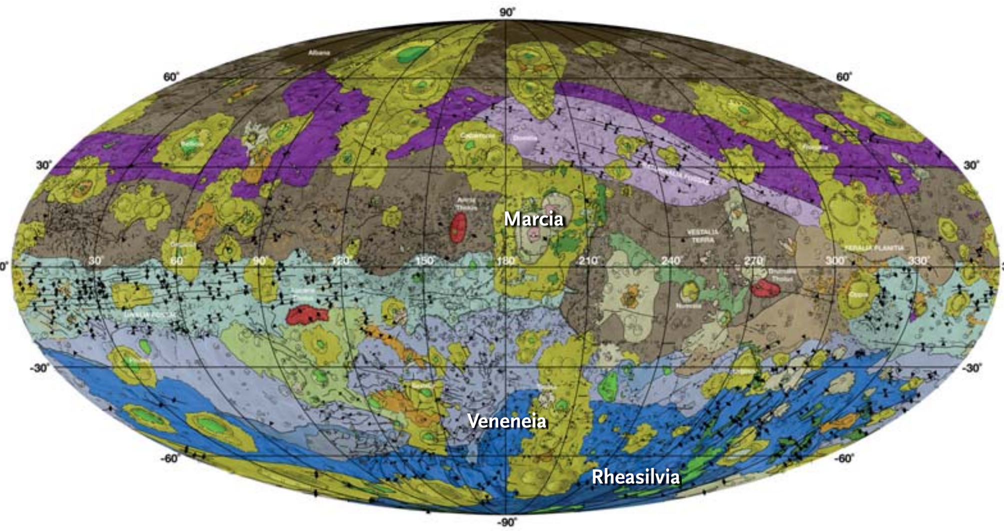
Explore the map in more detail at skypub.com/vestamap.

Geologists are always seeking to know the sequence of events that shaped a given solid body, and now they have a much better idea of what happened when on asteroid 4 Vesta. A detailed geologic map, a compilation of data from 11 papers in the December issue of *Icarus*, shows features large and small revealed by NASA's Dawn spacecraft during its 14-month-long survey of Vesta in 2011–12. It represents 2½ years of effort by David Williams (Arizona State University) and others.

Shown at right, the global map reveals that this oblong, 573-by-446-km body is divided into provinces pegged to the formation of its three largest craters. Roughly a third of Vesta's surface (shown as brown and tan hues) predates the excavation of 400-km-wide Veneneia basin near Vesta's south pole. A wide northern band (purple) represents terrain emplaced thereafter but before the formation of Rheasilvia, which in size is comparable to the diameter of Vesta itself. Ejecta from that blast are shown in blue hues. A final veneer (greens) followed the formation of 68-km-wide Marcia crater, one of the asteroid's youngest features.

But it's the "when" part of this chronology that's given Williams and his colleagues trouble. They deduce one set of ages when using a model based on the assumed cratering rate within the asteroid belt — and very different ages when attempting to extrapolate from cratering rates on the Moon and from the ages of lunar samples. For example, the Veneneia blast occurred either about 2.1 or 3.7 billion years ago, according to the asteroid or lunar model, respectively. Conversely, Marcia appeared either about 390 (asteroid) or 120 (lunar) million years ago.

■ **J. KELLY BEATTY**



NASA / JPL-CALTECH / ARIZONA STATE UNIVERSITY

Many geologic terrains mar the surface of Vesta. Black lines with geometric shapes denote different types of linear features, while colors associate features with different major impact events. The canyons around Vesta's equator possibly arose due to stress from the Rheasilvia impact.

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IN BRIEF

Eight Billion Oort Asteroids? A fresh look at asteroids moving in comet-like orbits concludes that asteroids must make up about 4% of the Oort Cloud (see page 26). The problem began with the discovery in 1996 of 1996 PW, which had the highly elongated orbit of a comet but looked like an asteroid. Since then, dynamicists have come to suspect that the giant planets' orbits changed dramatically in the early solar system, flinging small bodies everywhere. Writing in the January 11th *Monthly Notices of the Royal Astronomical Society*, Andrew Shannon (University of Cambridge, UK) and colleagues used computer simulations to confirm that lots of rocky bodies originally within 2½ astronomical units of the Sun should now be lurking among the Oort Cloud's half trillion comets. The estimated 8 billion objects matches an earlier calculation by Paul Weissman (JPL) and Hal Levison (Southwest Research Institute). If true, the Oort Cloud has more asteroids than detected in the main asteroid belt.

■ **J. KELLY BEATTY**

Evicted Black Hole or Odd Supernova? A weird source of radiation near the dwarf galaxy Markarian 177 might be a supermassive black hole kicked out of the galaxy. The source SDSS J113323.97+550415.8 lies 2,600 light-years from the dwarf's center and appears in archival observations going back to 1950. Both the object's variability and broad emission lines are typical of a gas-guzzling black hole with a mass of 1 million Suns. But the object's narrow Fe-II emission lines and 2.5-magnitude spike in 2001 better match a *luminous blue variable* star going supernova. Still, the star would have had to experience the largest pre-supernova mass loss ever recorded to explain the decades of above-average brightness, and even then the broad emission lines remain difficult to explain, Michael Koss (University of Hawai'i and ETH Zurich, Switzerland) and colleagues report in the November 21st *Monthly Notices of the Royal Astronomical Society*. Astronomers have found only a few candidate recoiling black holes, which they expect to be created during galaxy mergers.

■ **MONICA YOUNG**

SOLAR SYSTEM | Bright Spot on Uranus . . .

Uranus's weather has ramped up in the last few years, producing spots, scalloped edges, and other cloud features. Recent storms have been so large that amateur astronomers are spotting them, too.

When Imke de Pater (University of California, Berkeley) and colleagues detected eight large storms in the planet's northern hemisphere on August 5th and 6th, several amateurs also started looking. Among the successful observers was Australian amateur Anthony Wesley, whose composite infrared-RGB images appear at right. Despite heroic attempts, no amateurs have seen the storms visually.

ANTHONY WESLEY

A composite infrared-RGB image from September 19th (above, left) doesn't show a storm on Uranus, but one from October 2nd does.

The storm clouds are likely so bright due to high reflectivity. They're probably made of condensations of methane ice or other compounds.

The storm amateurs detected in October was fairly deep in the planet's atmosphere, tucked below the highest layer of methane ice. The professional team saw the same storm at the near-infrared wavelength of 1.6 microns back in August, using the 10-meter Keck II on Mauna Kea. Other features de Pater's team also detected at the longer 2.2 microns, meaning they're higher in the cloud deck, just below the tropopause.

The amateurs' storm might be part of a tall vortex anchored deep in the planet's atmosphere, similar to the Great Red Spot and other features on Jupiter.

■ **CAMILLE M. CARLISLE**

. . . and Target Crisis Averted for New Horizons

NASA scientists have found three potential Kuiper Belt objects (KBOs) in the nick of time, saving the Pluto-bound probe from missing out on half of its mission.

The mission plan calls for New Horizons to whiz 10,000 km above Pluto's surface in July 2015, then fire thrusters to set itself on a course to fly past a KBO. But finding a suitable KBO took three years of searching with both ground- and space-based instruments; planners postponed the main search until 2011, when for various reasons it became easier to look for objects near Pluto.

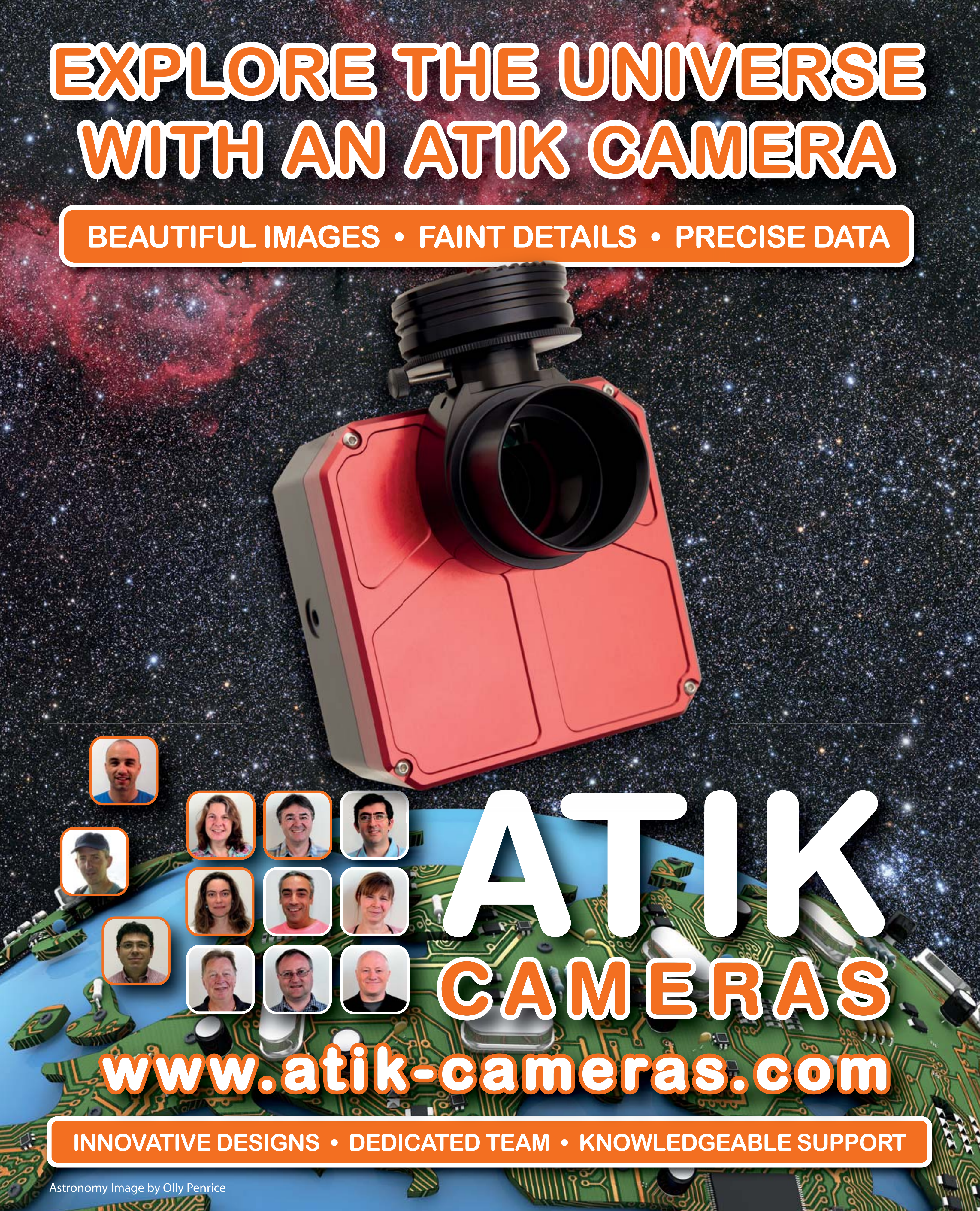
Hubble observations and "crazy amounts of rapid-fire data reduction, analysis, and follow-up" finally turned up the candidates, principal investigator Alan Stern (Southwest Research Institute) said when NASA confirmed the finds in October.

The first target, designated Potential Target 1, is roughly 30 to 45 km across. New Horizons could reach it in January 2019, and with only two-thirds of the spacecraft's remaining fuel supply.

The other targets, PT2 and PT3, are both slightly brighter and therefore bigger than PT1, which will make targeting them easier. Their larger surfaces also have a huge advantage. "By looking at their surfaces we can learn about how battered they have been by collisions over the years — how violent or quiet things have been in the outer region of our solar system," says team member Susan Benecchi (Planetary Science Institute).

The spacecraft emerged from electronic hibernation on December 6th, having spent a total of 1,873 days (two-thirds of its time in space) sleeping. It split this dormancy into 18 different naps ranging from 36 to 202 days long. By May, its images of Pluto should exceed the resolution of the best ones taken to date by the Hubble Space Telescope. ✦

■ **SHANNON HALL**



Astronomy Image by Olly Penrice

Edge-on Galaxies

There's something special about these slender streaks of light and dust.

Ted Forte

Perhaps it's the symmetry, the simplicity, or just the whimsical serendipity of finding an object so precisely aligned across our line of sight, but there's no denying that galaxies seen edge-on have a special allure. They're favorite targets for both visual observers and astrophotographers. They're also important targets for professional astronomers; their particular orientation enables measurement of stellar velocities along the length of the galaxy that can yield galactic rotation rate and reveal the object's mass. This makes edge-on galaxies important laboratories for, among other things, the study of dark matter.

The sky this month contains many interesting examples of galaxies that, by happy accident, are inclined close to 90° from our vantage point. Some of these slender streaks of light will be crowned with bright bulges; others will be bisected by bands of dark obscuring dust. Many will, by virtue of the optical depth of the light path, appear brighter than they would if seen from more open angles. And in contrast, some will be devilishly hard to detect due to their ultra-thin profiles. If you're new to deep-sky observing, I predict you'll find in this sampling a few objects that will amaze and inspire you, objects that you'll soon come to regard as favorites. Perhaps it will encourage you to seek out other examples of edge-on galaxies. There are many more in this month's sky than are mentioned here.

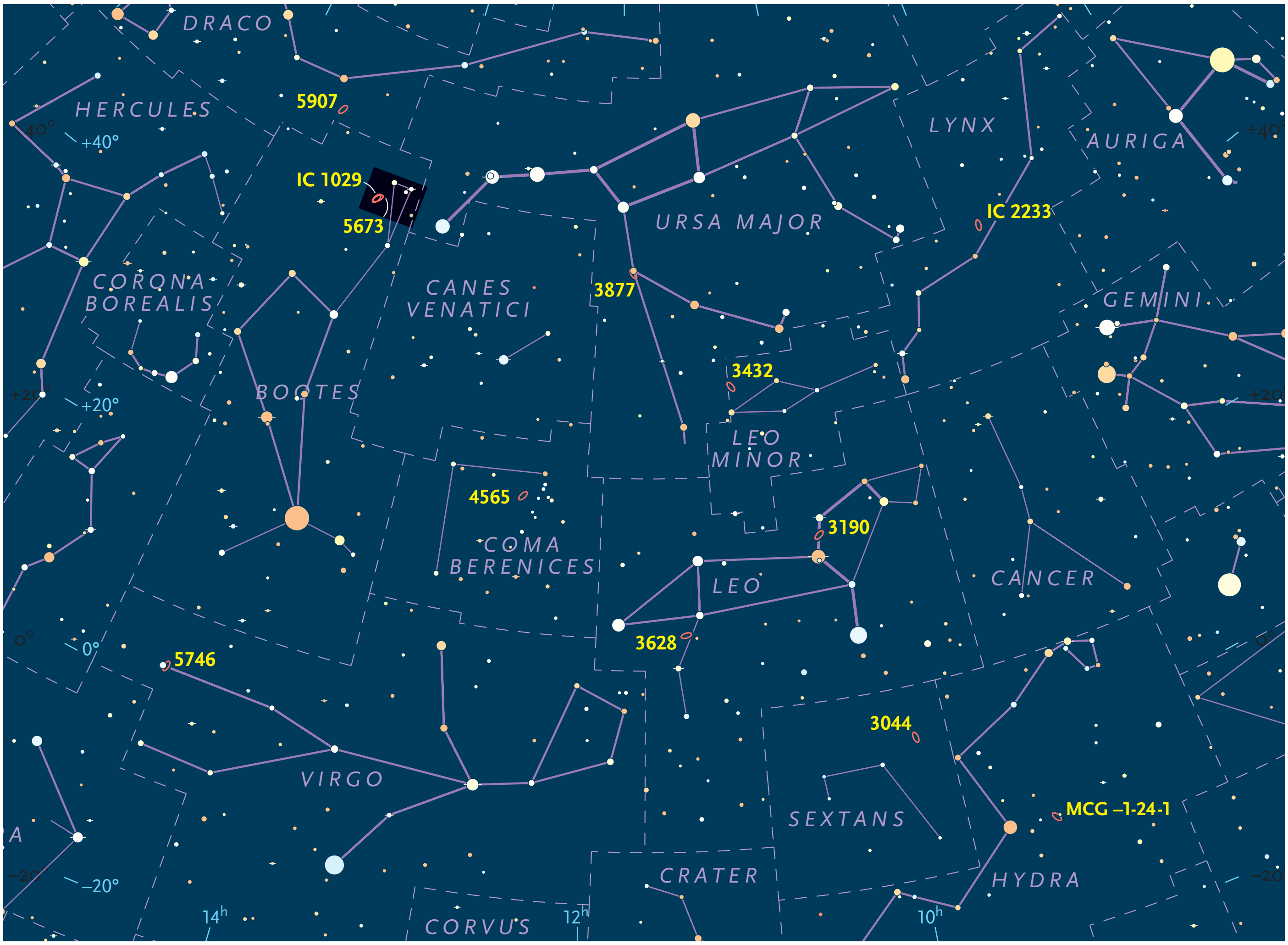
Following the same practice I used in my article on observing galaxy trios (*S&T*: Nov. 2014, p. 62), our tour contains only objects that should be detectable in telescopes with 10 inches of aperture from a transitional rural/suburban sky (Bortle Class 4, *S&T*: Feb. 2001, p. 126). In the table on page 24, I've assigned a difficulty score to each galaxy. The score is based on a seven-point scale, where 1 is easy in a 10-inch scope and 7 would be undetectable. Your own results are likely to vary depending on your telescope, skies, and experience level. I've also provided a recommended magnification that might optimize your chances of visual detection, similarly based on a 10-inch telescope. Consider this a reasonable starting point and adjust your magnification to suit your own tastes and conditions.

IC 2233

ESA / THE HUBBLE HERITAGE TEAM / NASA / LUCA LIMATOLA

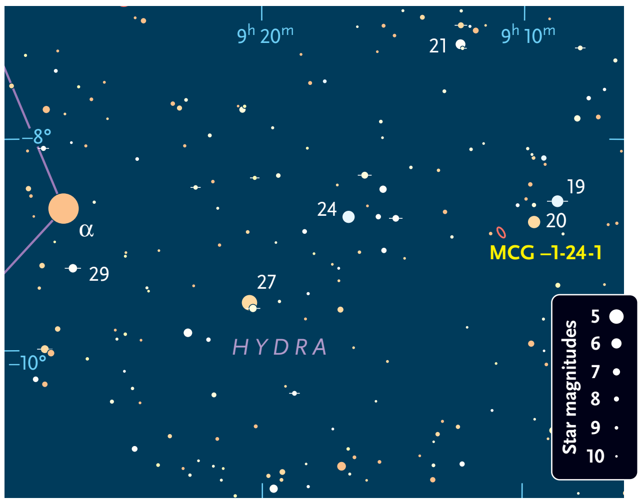
KEN CRAWFORD


NGC 4565



IC 2233 in Lynx is one of the flattest galaxies known, with an axis ratio of 8.9:1. It contains no visible bulge. Its ultra-thin profile led NASA to title a 2012 Hubble image the *Needle Galaxy*, a nickname shared with NGC 4565, which we'll visit later on our tour. This first needle is located 3° northwest of 31 Lyncis and lies about 40 million light-years from Earth. The galaxy shares a medium-power eyepiece field with NGC 2537, also known as the *Bear Paw Galaxy*, which lies about 17′ to the north-northwest. IC 2233 is aligned almost north-south and sits alongside a 10th-magnitude field star about a minute away to the east. Another 10th-magnitude star is almost 5′ to the west. This thin sliver of light can be challenging in moderate apertures. Use averted vision and try rocking the scope to pick it up.

Position angle (PA) is key for viewing elongated galaxies. PA is measured along the major (long) axis of the galaxy from 0–180° starting from the north and rotating toward the east. A galaxy that angles exactly north-south would have a PA of 0°; an east-west galaxy would have a PA of 90°. Determining the PA of a galaxy can be tricky because first you must know the orientation of your field of view. Turning off your scope's motor drive will help you determine it; the direction of star drift indicates where west lies. If your scope produces an inverted image, north will be counter-clockwise from west. If your scope produces a mirror-reversed view, north will be clockwise from west. A



telescope with an even number of reflections, like a typical Dobsonian, inverts the image. An odd number of reflections, such as in a Schmidt-Cassegrain or refractor with a star diagonal, mirror-reverses what you see.

Hydra contains the only non-NGC/IC galaxy on our tour. To find **MCG –1-24-1**, look 4.5° west of Alpha (α) Hydrae, where your finder should easily pick up the nearly equal magnitude pair 19 and 20 Hydrae. Our target is an easy star hop from there, lying just 19.25′ east-southeast from 20 Hydrae. Detection of this slender beauty would be rather straightforward were it not for the 9th-magnitude star close alongside to the west. The star effectively hides the galaxy and might be the reason it doesn't appear in the NGC or IC catalogs. Without foreknowledge of its presence, it would be a very lucky catch indeed, but by using the star to pinpoint the galaxy's exact location, you should be able to detect it. You'll be tempted to strain, but resist that urge; a relaxed eye is much better at detecting faint objects. You might find that the object will pop into view if you look away, relax your eye, and try again. Angled just a little east of north, its position angle is 18°. Don't be discouraged if you find it difficult to make that estimate; it's a challenging thing to accomplish with an object that your eye can't fix with steady vision.

Our next streak-like galaxy lies about 54 million light-years away in the direction of Sextans. **NGC 3044** is moderately faint with a slightly brighter middle; it's angled northwest-southeast at position angle 112°. In large aperture, the bright center has a knotty appearance. Star hop from 7 Sextantis, which lies almost halfway between Alpha Leonis and Alpha Hydrae. The galaxy is just under a degree away to the southeast; a triangle of 9th-magnitude stars northeast of the galaxy points the way.

The head of Leo contains a compact group of four galaxies, designated Hickson 44, that resides almost halfway between Zeta (ζ) and Alpha Leonis. The edge-on galaxy **NGC 3190** is one of the brighter members of the group that lies almost 80 million light-years away from us. The galaxy has a bright core with a stellar nucleus. Owners of large scopes should try to detect a very subtle dust lane that appears slightly skewed from gravitational interaction with other group members.

Halfway between Psi (ψ) and Mu (μ) Ursae Majoris is our next target, **NGC 3432**, an edgeways streak in Leo Minor. This fine edge-on is probably interacting with a dim dwarf galaxy about 3′ to the west-southwest that isn't detectable in moderate aperture scopes. NGC 3432 is also known as Arp 206, one of the 338 galaxies comprising Halton Arp's *Atlas of Peculiar Galaxies* (1966). It has a bright, dappled core and a disturbed-looking halo. There

KEN CRAWFORD

SHERRY AND STEVE BUSHEY / ADAM BLOCK / NOAO / AURA / NSF

Edge-On Galaxies

Object	Const	Mag (v)	Size	RA	Dec	Score	Power
IC 2233	Lyn	12.4	4.7′ × 0.6′	8^h 14.0^m	+45° 45′	3	150×
MCG –1-24-1	Hya	12	5.0′ × 0.9′	9^h 10.8^m	–08° 53′	4	120×
NGC 3044	Sex	11.9	4.8′ × 0.9′	9^h 53.7^m	+01° 35′	4	100×
NGC 3190	Leo	11.1	4.4′ × 1.5′	10^h 18.1^m	+21° 50′	3	100×
NGC 3432	LMi	11.4	6.8′ × 1.5′	10^h 52.5^m	+36° 37′	3	85×
NGC 3628	Leo	9.8	14.8′ × 3.0′	11^h 20.3^m	+13° 35′	3	40×
NGC 3877	UMa	11.3	5.5′ × 1.3′	11^h 46.1^m	+47° 30′	3	100×
NGC 4565	Com	9.5	15.8′ × 2.1′	12^h 36.4^m	+25° 59′	3	65×
NGC 5673	Boo	13.4	2.5′ × 0.6′	14^h 31.5^m	+49° 58′	4	150×
IC 1029	Boo	12.2	3.0′ × 0.7′	14^h 32.5^m	+49° 54′	3	150×
NGC 5746	Vir	10.8	7.4′ × 1.3′	14^h 44.9^m	+01° 57′	3	120×
NGC 5907	Dra	10.7	12.6′ × 1.4′	15^h 15.9^m	+56° 20′	3	100×

The difficulty score ranges from 1 (easy) to 7 (undetectable) as described in the main text. 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.

are three stars close by, a pair on the southwest tip and another star alongside to the southeast.

NGC 3628 in Leo has two popular nicknames. While many purists bemoan the assignment of these whimsical monikers, I think handles such as *Sarah's Galaxy* adds interest to the objects that earn them. "Sarah" might refer to a 19th-century poet, but any definitive, authoritative source for the name seems lost. NASA's APOD images of NGC 3628 are labeled *Hamburger Galaxy*, and inevitably some observers will associate the galaxy with that title. Most of us, however, know NGC 3628 as the third and faintest member of the Leo Trio or Leo Triplet. It's a fascinating object, well worth the extra effort it takes to detect its subtleties. The galaxy, 100,000 light-years across and 35 million light-years away, contains a significant dust lane. Spectroscopic analysis of NGC 3628 reveals that the stars in its disk orbit opposite to the dust that comprises the galaxy's most prominent feature. This odd circumstance, it's thought, is evidence of a recent merger. The galaxy seems warped too, the flaring of its edges no doubt a result of gravitational interaction with its Messier neighbors. Look for NGC 3628, along with its companions M65 and M66, about 2.5° southeast of Theta (θ) Leonis.

Look 17′ south of Chi (χ) Ursae Majoris to find **NGC 3877**. It's oriented northeast-southwest at a PA of about 35°. Its bright, elongated core fills most of its visible length; a fainter halo increases its overall dimensions only slightly. You'll need about 10 inches of aperture to see the mottled texture of the core and an even larger scope to distinguish individual knots. NGC 3877 is a member of the M109 group of galaxies and lies about 50 million light-years away.

Coma Berenices contains what I consider to be one of the most spectacular edge-on galaxies in the northern sky. **NGC 4565** is sometimes known as the *Needle Galaxy* but might be better known as *Berenice's Hairclip*. It's beautiful for its perfect symmetry and impressive due to its large size. A bright oval bulge is flanked by a well-balanced disk, its two gracefully tapering segments neatly bisected by a prominent dust lane. Choose a magnification that fills your field of view and you cannot help but be impressed. NGC 4565 lies just east of the large naked-eye cluster Melotte 111. Find it on the imaginary line connecting Alpha and Gamma (λ) Comae Berenices, approximately 3° from Gamma.

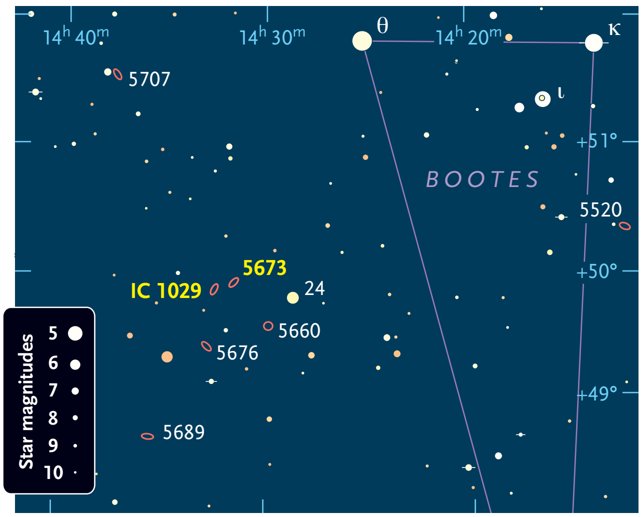
About 7° east of Eta (η) Ursae Majoris, you can pick up two nice edge-on galaxies in the same field of view. **NGC 5673** and **IC 1029**, both in Boötes, are just 9.5′ apart. NGC 5673 is small and faint with a stellar core. It's perhaps 100 million light-years away. A 13th-magnitude star resides at its northwest tip. IC 1029 is a little larger, a little brighter, and has a very much brighter core. At 110 million light-years, it's also just a bit further away.

NGC 5746 is in Virgo, just 20′ west of the naked-eye star 109 Virginis and perhaps 95 million light-years

BRAD EHRHORN / ADAM BLOCK / NOAO / AURA / NSF

from Earth. It's oriented nearly north-south and has a bright bulge and a prominent dust lane. The disk itself is diffuse, the opposing projections fading away without a sharp edge. Photographs show a very boxy core that might indicate a barred spiral, but that box-like center isn't noticeable visually. An 8.5-magnitude field star sits about 5′ northwest of the galaxy.

We'll end our tour with the *Splinter Galaxy*, **NGC 5907** in Draco. Even a 4-inch scope will reveal a faint sliver here; in large apertures, it's a rather impressive sight, a fitting wrap-up to this expedition. This graceful beauty is large and brilliant, with a brighter core that itself is a bit elongated. Its dust lane is subtle: the glowing core overwhelms it, but it's faintly detectable along the flanks of the disk, especially on the west side. See if you can detect two faint stars, one that hugs the west side of the halo and another just off the northern tip. At 14th-magnitude, these two are quite a challenge. The Splinter is located about 3° south-southwest of Iota (ι) Draconis.

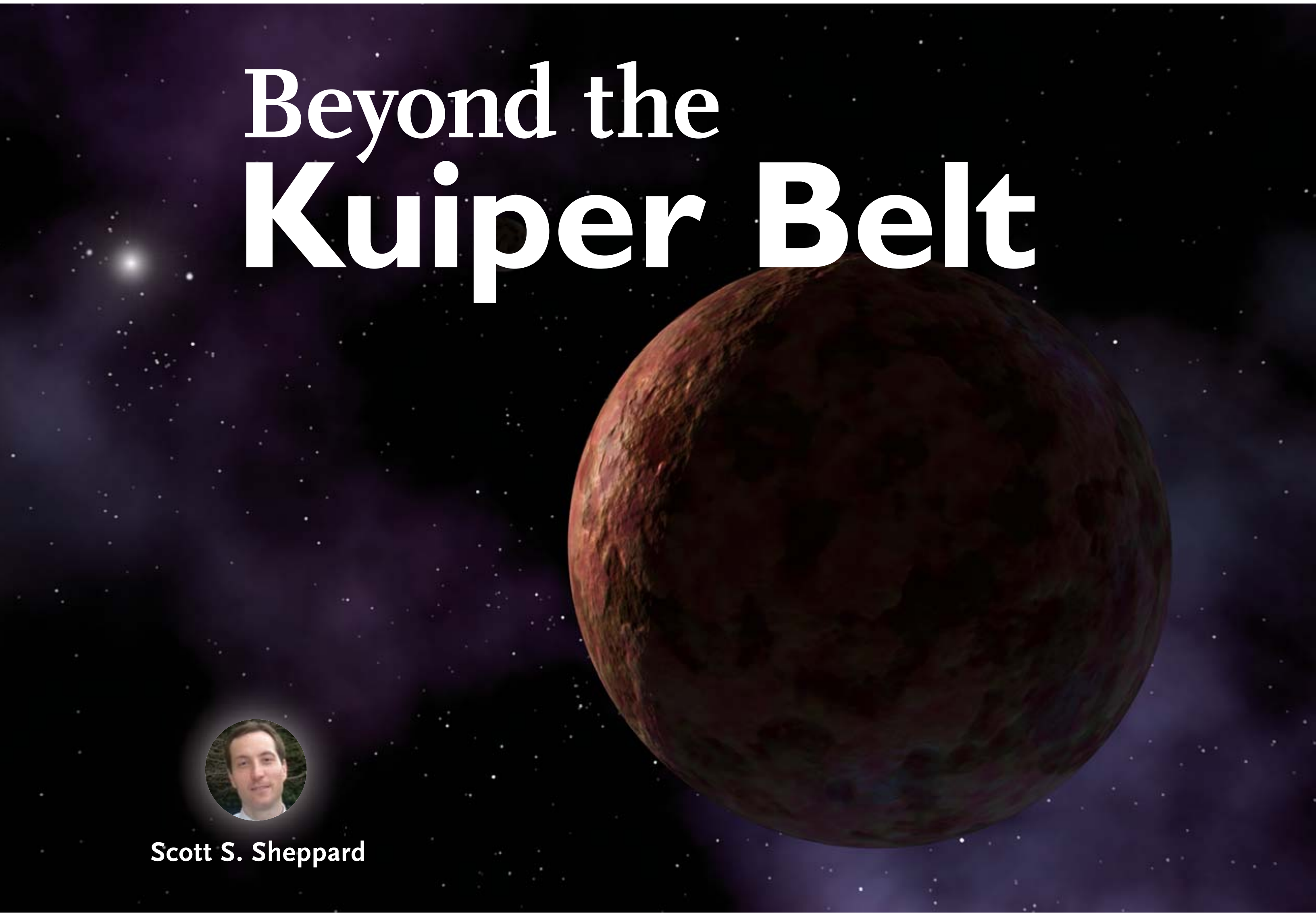


It's so easy to get lost in the mechanics of detecting these faint patches of light that we might lose sight of the real significance of what it is we're capturing. I urge you not to let that happen. Galaxies may be viewed through the eyepiece, but they're appreciated through the imagination. Part of the fun of observing has to be the flights of fancy that transport us to realms far beyond our galactic neighborhood and to worlds well beyond our reach. As the science of astronomy advances, so too does the reach of our mind's eye. Understanding the true nature of these distant domains has provided us with an exponential expansion of our universe. For now at least, we can only explore that universe remotely, via journeys of thought taken through the telescope. ✦

*Contributing Editor **Ted Forte** observes from his home near Sierra Vista, Arizona. He pens a monthly astronomy column for his local newspaper, the* Sierra Vista Herald.

Beyond the Kuiper Belt

Scott S. Sheppard



NASA / JPL-CALTECH / ROBERT HURT (SSC)

Many bodies likely lurk in the sprawling emptiness that fringes our solar system. Where are they, and how did they get there?

In 1781 William Herschel discovered Uranus, the first planet not easily observable with the naked eye. Astronomers found Uranus's orbit to be peculiar, as if a more distant planet's gravity pulled on it. A search for this unseen planet led to the discovery of Neptune in 1846. Neptune's motion was also thought to be peculiar, which led to the discovery of Pluto in 1930.

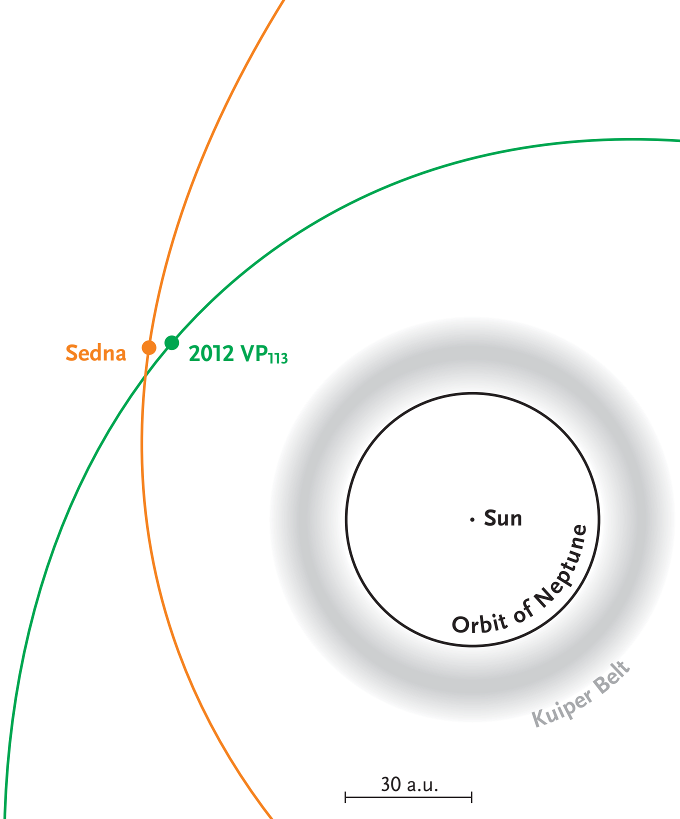
But astronomers have now determined that Pluto is only about 2,322 km (1,443 miles) in size, which is smaller than Earth's Moon, and not massive enough to affect Neptune's orbit. Later observations revealed that Neptune's motion was as expected, and no massive perturber was called for.

Our exploration of the outer solar system was just beginning, however, and it continues today, with new discoveries and new mysteries arising all the time. Beyond Neptune lies an expanse of icy bodies, only a relative handful of which we've detected. And we're still figuring out how these mini worlds wound up where they are today.

DISTANT ENIGMA Sedna (above, in an artist's conception) was discovered in 2003 far beyond Pluto and the classical Kuiper Belt. Do other large bodies like Sedna exist in the far reaches of our solar system? Astronomers are avidly searching for them.

The Kuiper and the Oort

Some 2,000 objects are known to orbit in the area near Pluto, which is now called the Kuiper Belt (*S&T*: Feb. 2014,



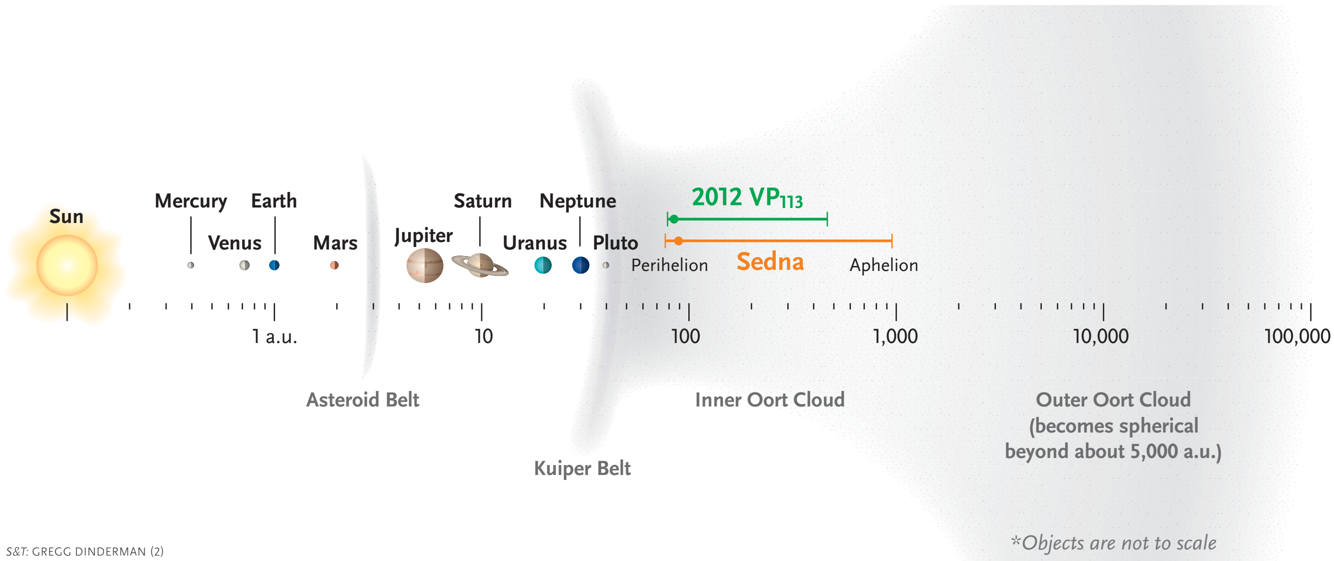
PATH NOT TAKEN The orbits of Sedna and 2012 VP_{113} lie entirely outside of Neptune's. But their highly elliptical orbits mean they interacted with *something* in the past.

p. 18). The Kuiper Belt appears to have an edge around 48 astronomical units, or 48 times the Sun-Earth distance, at which point the number of objects falls off sharply. The Kuiper Belt is a remnant of the original solar nebula out of which our planetary system formed, but it is made of the material that couldn't coalesce into a planet due to the large volume of space and low density of matter so far from the Sun. In fact, it is so hard to form objects in the outer solar system that Uranus and Neptune likely didn't form where they are now but were pushed out through interactions with Jupiter and Saturn.

Short-period comets, which have semi-major axes of only a few to tens of a.u. and low-inclination orbits, are likely recent escapees from the Kuiper Belt. Although the main Kuiper Belt ends around 48 a.u., there is another large reservoir of objects in the distant solar system from which the long-period comets originate. Long-period comets generally have semi-major axes of tens of thousands of a.u. and have orbits tilted every which way compared with the planets' nearly flat orbital plane (the planets essentially all lie in the ecliptic).

The reservoir that supplies these comets is called the Oort Cloud after Jan Oort, the Dutch astronomer who first proposed such a reservoir in 1950. The Oort Cloud extends over one-third of the way to the nearest stellar system, Alpha Centauri, or about 100,000 a.u. It likely contains around a trillion objects larger than 1 km across, with orbital periods of a few million years. It is well beyond the heliosphere, the region that ends where the solar wind gives way to the interstellar medium and through which the Voyager probes are now passing at around 120 a.u.

The Oort Cloud likely arose during our solar system's planet-building epoch. During our solar system's formation, many sizable objects formed in the giant planet region. Most of these objects became incorporated into the planets, but gravitational interactions with the growing planets tossed some from the region. The majority of these objects were ejected from the solar system into interstellar space, but 1 to 10 percent would not have had



S&T: GREGG DINDERMAN (2)

TOWARDS THE OORT As this diagram shows, Sedna and 2012 VP_{113} lie in a far-flung region of our solar system that some astronomers refer to as the inner Oort Cloud (IOC). Experts suspect that the population of objects in the IOC may be larger than that of the Kuiper Belt.

enough energy to escape and thus would have ended up in the distant outer solar system.

An object thrown outwards that does not escape the Sun's gravity will have an elliptical orbit that might take it to thousands or tens of thousands of a.u. But the orbit will still have a closest approach to the Sun (perihelion) that brings it back to the location from which it was originally scattered out. Thus any scattered object will still have part of its orbit within the giant planet region (5-30 a.u.) and at some point will strongly interact with the massive planet again. This will lead to either an eventual collision or complete ejection from the solar system.

The Oort Cloud assembled from these eccentric objects at thousands to tens of thousands of a.u., where they are weakly bound to our star. This is where the gravity of the Sun wanes to the point that the gravitational influence of nearby stars, the galactic center, and the Milky Way's disk start to be significant. This tidelike effect can move an object's perihelion out far enough past the planets to a point beyond any further strong interactions with Jupiter and its kin. This interaction randomizes inclinations and orbits of Oort Cloud objects over time, and it causes some of them to be lost into interstellar space while others are thrown back into the planetary arena to be observed as long-period comets.

The inner solar system may actually experience comet showers from random close stellar encounters. These are rare events when a star passes within about 100,000 a.u. of our Sun. Such events, which happen every few tens of millions of years or so, likely only increase the comet flux by a few tens of percent. The next known close encounter will be with the star Gliese 710, which will pass about 70,000 a.u. from our Sun in 1.5 million years. Researchers have suggested these stellar encounters could cause extinction events here on Earth by triggering a storm of comet impacts on the surface, but the interactions are very difficult to predict.

The Inner Oort Cloud

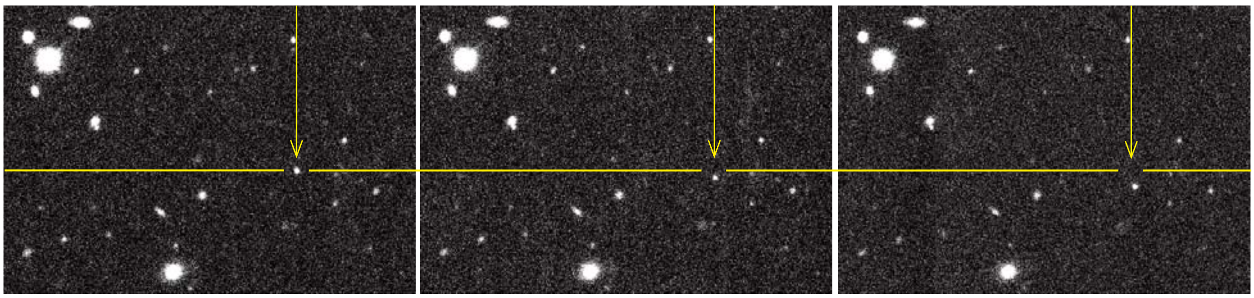
So what about the no man's land between the Oort Cloud at thousands to tens of thousands of a.u. and the Kuiper Belt at a few tens of a.u.? Astronomers had thought no objects would exist with orbits entirely in this middle region, since here the galactic tide is not strong enough to move the perihelion of an object out of the planetary region.

Then Sedna was discovered in 2003, in a shallow survey using the 1.2-meter Samuel Oschin Telescope at Palomar that covered most of the observable sky in the Northern Hemisphere. About 1,000 km in size, Sedna became the first object known to occupy this empty quarter for its entire orbit, with a perihelion of 76 a.u. and semi-major axis of 532 a.u. It was so unusual and unexpected that astronomers had to rethink the formation of our solar system. Ten years later, Chad Trujillo (Gemini Observatory) and I discovered 2012 VP_{113}, which has a perihelion even farther away than Sedna's at 80 a.u., though surprisingly it has a smaller semi-major axis (265 a.u.). Both objects are on very stable orbits. These objects currently do not interact significantly with any known mass in our solar system, including Neptune. However, their highly elliptical orbits mean that they must have interacted with *something* at some point in time.

Some astronomers have called these inner Oort Cloud (IOC) objects, since they are not susceptible to the galactic tide like the more distant outer Oort Cloud objects at thousands of a.u. IOC objects thus follow orbits that have remained stable from primordial times and are essentially fossilized imprints from their formation mechanism.

Theorists have proposed several viable IOC formation scenarios, all of which require the solar system to have been in a state vastly different than it is now. One theory is that a small rogue planet, tossed out of the giant planet region, could have dragged smaller objects with it or perturbed objects out of the Kuiper Belt and into the IOC on its way out. This planet could have been entirely ejected from the Sun's family of bodies or still be lurking in the distant solar system today.

Another theory is that IOC objects are captured objects that were ejected from other star systems that happened to be near our Sun during its formation in the original birth cluster (*S&T*: Mar. 2012, p. 30) and were then swept up by our star. A third, related theory is that a close stellar passage to our Sun sometime over the age of the solar system could have created objects like we see in the IOC



SCOTT SHEPPARD / CARNEGIE INST. FOR SCIENCE

FAINT TRAVELER On November 5, 2012, the author, together with Chad Trujillo, discovered the inner Oort Cloud object known as 2012 VP_{113}. The discovery images above were taken about two hours apart with the Dark Energy Camera on Cerro Tololo in Chile.

T. ABBOTT AND NOAO / AURA / NSF

GOOD EYE **The Blanco 4-meter telescope at the Cerro Tololo Inter-American Observatory in Chile. The author and Chad Trujillo used the telescope's Dark Energy Camera to take the discovery shots shown on page 28.**

either by tugging objects in our solar system outwards or losing objects to our Sun (or both), but such a passage would have to have been within a few hundred a.u. This is very unlikely and would probably have disrupted the outer Oort Cloud.

But the leading scenario is that the IOC objects are native to our Sun and came to inhabit the region they do during a time when the gravitational tugs from outside were much stronger on the solar system than they currently are. This stronger tide would have perturbed objects closer to the Sun and been able to move their perihelia out to our system's outer reaches. A stronger tide would have occurred during our Sun's genesis in its birth cluster, as many other star systems were nearby. Theorists have simulated such a situation, finding that if our Sun originated in at least a moderately dense birth cluster (with a core packing 300 solar masses or more in a single cubic light-year), the gravitational interaction of our system with other stars could have produced IOC objects like Sedna and 2012 VP_{113}. Thus the creation of the IOC suggests our Sun grew up with a lot of siblings, which today are dispersed throughout the galaxy.

All the above theories are testable, with each predicting different orbital distributions for the IOC population. For instance, 2012 VP_{113} is more tightly bound to the Sun than is Sedna, meaning it would need a bigger outside perturbation to raise its perihelion. If IOC objects are captured extrasolar objects, they should have an assortment of orbital inclinations to the ecliptic, as capture should not strongly depend on the direction the objects came from. Objects scattered out from the inner solar system should show a flatter inclination distribution, reflecting their origin near the plane of the planets.

The modest inclinations of Sedna (12°) and 2012 VP_{113} (24°) suggest they formed within our solar system. Sedna's extremely red color also correlates well with the known classical Kuiper Belt objects. 2012 VP_{113}'s more moderately red color suggests it formed in the giant planet region. We need a bigger sample to say much more about the IOC objects.

What's Still Out There?

Sedna was discovered using the largest digital camera at the time to survey the sky efficiently. 2012 VP_{113} was discovered because astronomers are now placing these big digital cameras on larger telescopes. The Dark Energy Camera on the Blanco 4-meter telescope at the Cerro Tololo Inter-American Observatory, which Chad and I used to discover 2012 VP_{113}, covers about 2.7 square degrees per image. This is a factor of several times more sky area than any previous camera on a 4-meter or larger telescope, encompassing about 11 full Moons in one image. We are continuing our survey for distant objects and expect to find several more IOC objects in the next few years, but we will only cover a fraction of the sky. The Large Synoptic Survey Telescope, which the National Science Foundation is building in Chile, will cover a much larger portion of the sky and to the faint magnitudes needed to discover IOC objects in bulk. But it is still a decade away.

From the discovery of Sedna and 2012 VP_{113} and the small amount of sky searched to date, we believe about 1,000 objects larger than 1,000 km in size exist in the IOC, as well as many more smaller ones. The IOC population is likely larger than the main asteroid belt or Kuiper Belt. Several are probably bigger than Pluto, and some could even be bigger than Mars or even Earth. Objects get very faint at far distances, so big objects could easily lurk in the outer solar system (*S&T*: Mar. 2010, p. 20). We discover objects by their scattered sunlight, which has to travel out to the object, reflect off its surface, and travel back to Earth. An object twice as far away is 16 times fainter. Because of this, we can only detect Sedna and 2012 VP_{113} for a fraction of their orbits, when they happen to be near their perihelia. We would not spot these objects or even Mars-size objects on similar orbits most of the time because they would be too distant and thus too faint.

No more giant planets likely hide in our solar system, as NASA's Wide-field Infrared Survey Explorer spacecraft would have detected these large planets' warm atmospheres in the infrared. Giant planets give off more heat than they receive from the Sun, because their atmospheres are still dissipating energy they acquired from the planet's formation. Smaller worlds with minimal atmospheres, however, would be cold and frozen with no detectable heat signatures.

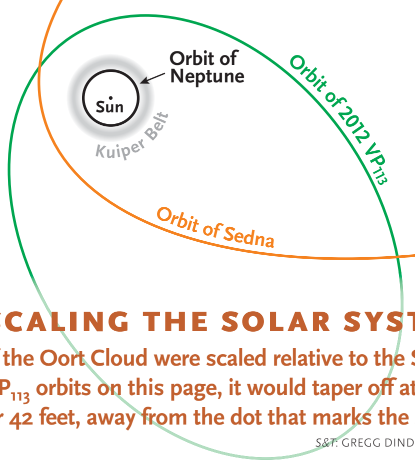
Some circumstantial evidence exists that a big object lies in the outer solar system. When looking at the orbits of Sedna and 2012 VP_{113} as well as 10 extreme Kuiper Belt objects near the outer edge of the Kuiper Belt, Trujillo and I noticed a similarity: a similar *argument of perihelion* for all 12 objects. The argument of perihelion is the angle at which an object comes to perihelion with respect to the ecliptic plane. Zero degrees means the object comes to perihelion in the ecliptic plane, while 90 degrees means it comes to perihelion at its greatest inclination away from the ecliptic plane. All 12 of the extremely distant objects have arguments of perihelion within a few tens of degrees of zero. This is unexpected, because the argument of perihelion is expected to be random for each object. One possible explanation is that a massive unknown perturber is shepherding these objects into these similarly angled orbits. These 10 known extreme Kuiper Belt objects could have formed in a similar manner to Sedna and 2012 VP_{113}, but past interactions with Neptune are also a possibility, as the perihelia of these objects are more within Neptune's reach.

The chemical composition of the distant objects is largely unknown, but Sedna appears to have methane ice on its surface. IOC objects are likely frozen ice balls that could be part of what the planets formed from, providing needed volatiles and organics for life here on Earth and possibly elsewhere. Determining their compositions and where and how they got to their present locations will tell us details about our Sun's birth environment and our solar system's formation. To answer these questions we need to find many more IOCs, in order to look for trends in the population's physical and dynamical characteristics. The hunt is on. ✦

Scott S. Sheppard is an astronomer in the Department of Terrestrial Magnetism, Carnegie Institution for Science (Washington, D.C.). If Guinness World Records *had a record for moon discoveries, Sheppard would hold it.*

LSST

WIDE-FIELD WONDER **When operational, the Large Synaptic Survey Telescope facility, here shown in a photo-simulation composite, will provide time-lapse digital imaging of faint astronomical objects such as those found in the inner Oort Cloud.**



SCALING THE SOLAR SYSTEM

If the Oort Cloud were scaled relative to the Sedna and 2012 VP_{113} orbits on this page, it would taper off at about 506 inches, or 42 feet, away from the dot that marks the Sun.

S&T: GREGG DINDERMAN

Phoenix Planets

The death of a star often has fatal consequences for orbiting planets. But for some worlds, the end of the stellar line could mean a brand-new start.

Nola Taylor Redd

We often think of stars and planets as living in lockstep. Most of the known planets in the galaxy formed at the beginning of their suns' lives, grown from clumps in the disks of gas and dust surrounding the young stars. Stars and their planets then eke out billions of years together, with infrequent interruptions. The death of the star in a planetary system often also spells the end for the planets: a supernova or a swelling red giant can easily demolish close-in planets and affect the orbits of distant ones.

Yet astronomers have discovered some planets orbiting older, evolved stars that do not look like they weathered the stars' deaths. Instead, these exoplanets seem to be much younger. Although few in number, such bodies could potentially make up a class of second-generation planets that formed at the end of their stars' lives, rather than at the beginning.

PULSAR PLANETS In 1992 astronomers discovered the first exoplanet system, around the pulsar PSR 1257+12. Two of the three planets are a few times Earth's mass; the innermost is slightly less massive than Mercury. Charged particles from the pulsar would probably rain down on the planets, creating auroras (shown on the outermost planet in this artist's impression).

NASA / JPL-CALTECH / ROBERT HURT (SSC)

Arising from the Ashes

In 1992, Aleksander Wolszczan (now at Penn State University) and Dale Frail (NRAO) discovered the first planets outside the solar system. To the surprise of many scientists, the two extrasolar bodies didn't orbit a Sun-like star; instead, they orbited a pulsar.

These stellar corpses act as very exact clocks, sweeping their lighthouse-like beams of energy around as they spin at a rate that's so dependable that astronomers can sometimes track it to a precision of twelve decimal places or more. The two planets the team found in orbit around the pulsar PSR 1257+12 created a measurable drag that affected the pulse, enabling the observers to detect the planets. A third planet was also soon confirmed.

Lying less than half the distance from their star as Earth lies from the Sun, these close-orbiting planets could not have survived the supernova explosion that created the pulsar. Astronomers quickly classified them as second-generation bodies.

After a surge of interest, attention waned when no similar systems were discovered (the next pulsar planet wasn't confirmed for several years). But in 2007, Brad Hansen (UCLA) and Thayne Currie (now at the National Astronomical Observatory of Japan) decided to revisit pulsar planets, applying the information learned about planetary formation over two decades. Their simulation of the system suggested that, after the star's death, some of the debris material would not leave the system. Instead, roughly a thousand solar masses could have remained bound to the pulsar, creating a disk of material with enough solid grains in the innermost section to build PSR 1257+12's three known planets. The planets therefore would have formed from the ashes of the dead star.

Binary Mergers and Dusty Giants

Not all stars explode in violent supernovae at the end of their lives. Stars with masses less than 10 times that of the Sun swell up into red giants. In the Sun's case, the expanding diameter will engulf Mercury and Venus in a few billion years and endanger Earth as well.

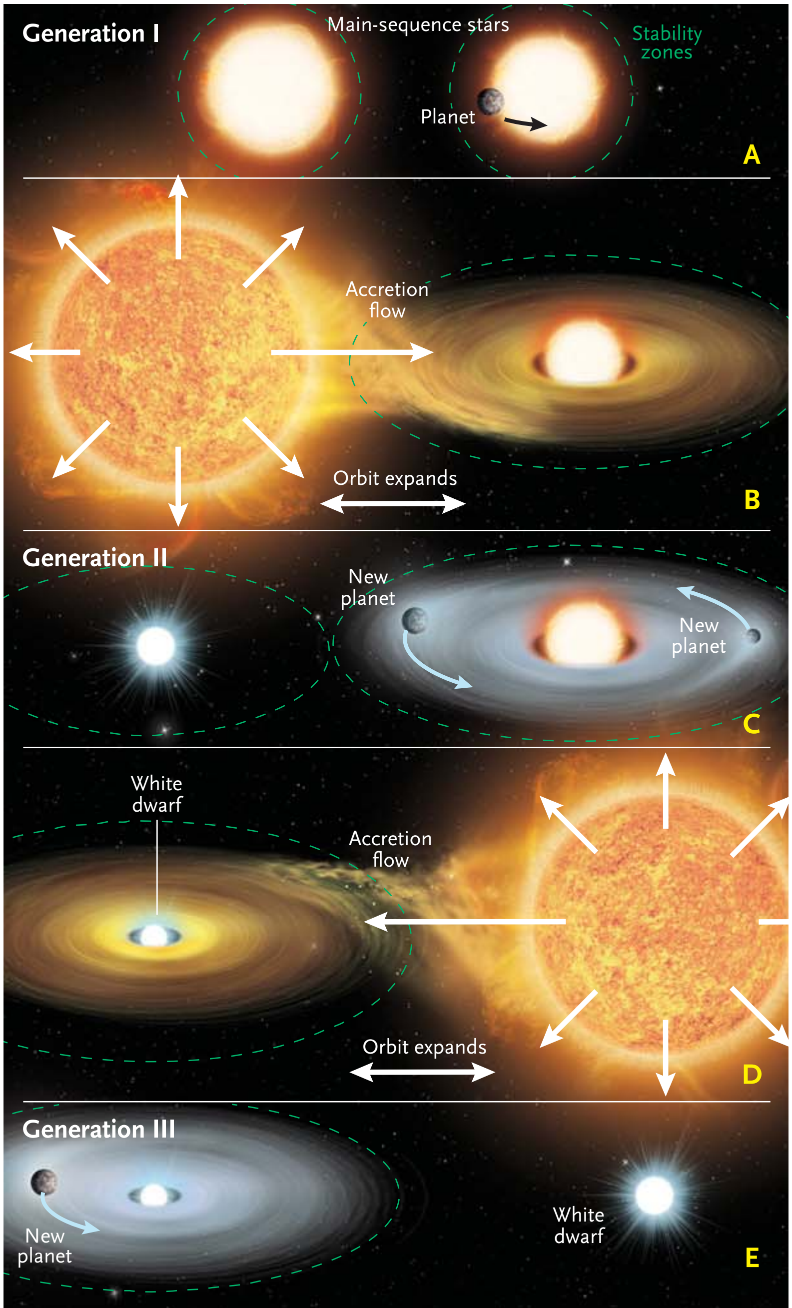
If a star is part of a close binary system, it could easily swallow up its companion star, shredding it to create a disk of material with the potential to birth second-generation planets. (Hansen and Currie also explored this idea but found it couldn't explain PSR 1257+12's planets.)

Carl Melis (University of California, San Diego) studies the dusty disks around red giants. He was originally searching for dust disks around main-sequence stars, but in a survey of nearby dust-shrouded objects, he realized that most of the dusty objects he spotted were instead giant stars, a find he deemed "serendipitous."

"No giant star had ever been discovered with copious amounts of dust in its planetary system," Melis says.

Today, Melis has around 20 disk-surrounded stars he is working to confirm are merged binaries, a time-consuming process that requires identifying the amount of gas in the disk. Knowing how much gas is present will allow him to rewind the system to determine if a merger could have formed it.

The material created by a merged binary would bear a strong similarity to the protoplanetary disk that formed early stars, Melis says, with similar conditions in both. But depending on how advanced the swallowed star's fusion was, the giant's disk might contain more heavy elements, dredged up from inside the parent star. The levels would not be as high as those in a pulsar's disk, but any increase in heavy elements



HOW PLANET GENERATIONS FORM Planets can form at multiple stages in stars' lives. A planet orbiting a main-sequence (core-hydrogen-fusing) star in a binary system occupies a gravitationally stable region (A). When the more massive star in the binary evolves to be a swollen red giant, its outflow can form a disk around the secondary star that is similar to the protoplanetary disk around young stars (B). The mass loss causes the binary's orbit to expand, and planets can form in the accretion disk (C). (The first-generation planet might or might not survive.) When the secondary star evolves, its outflow also engulfs the white dwarf in a disk of material (D). The same orbit expansion and planet formation as in (C) can now happen around the secondary (E). The final giant phase of a star's life lasts a few million years, roughly the lifetime of a first-generation disk.

S&T: GREGG DINDERMAN

could affect planet formation: on one hand, gas planets form more readily around metal-rich stars; on the other hand, rapid gas dispersion might keep the disk's mass low, making it difficult to produce gas giants.

"It's hard to say if giant planets would be less likely to form in giant star disks," Melis says. "My gut instinct says that it probably would be harder, but I don't have evidence to support that feeling yet."

Smoking Guns in Evolved Binaries

If a red giant is part of a binary system that doesn't merge, it could still form an environment where second-generation planets might bloom. Material blown off of the giant star by stellar winds could be trapped in orbit around its companion, forming a disk similar to those that form young planets. Ultimately, the giant star loses enough mass to shrink down to a white dwarf, no longer undergoing fusion at its core. But its debris could serve as the building blocks of planets around its still-shining companion star.

One such binary system is Gliese 86. Composed of a white dwarf and a main-sequence star, the system boasts a massive planet closely orbiting the star. According to Hagai Perets (Israel Institute of Technology), Gliese 86 is a "smoking-gun case" of a second-generation planet.

Before the system evolved, the original binary pair orbited far too close to allow a giant planet to evolve and maintain a steady orbit around its host star. But as the more massive star blew off its outer layers, the two stars would have drifted apart. If the giant planet formed from the material flowing off the giant star after the orbit of the binary pair extended, it would explain how the planet safely formed and migrated to inhabit the orbit it now does.

A second possibility is that an existing, first-generation terrestrial planet served as the seed for the gas giant. The terrestrial planet could have survived the stellar evolution, gathering material thrown off the giant star to grow into a massive gaseous planet.

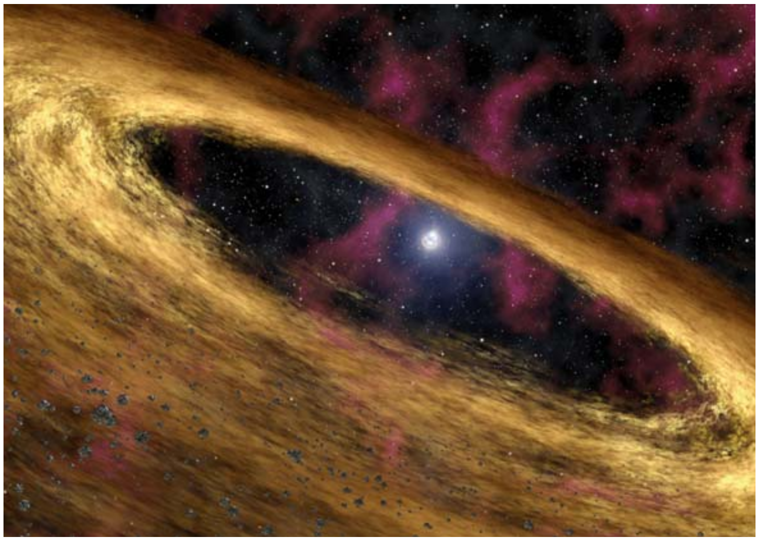
Another strong candidate for a second-generation planetary system is PSR B1620–26, a binary system featuring a pulsar and a white dwarf. A planet slightly more massive than Jupiter orbits both stars. The pulsar–white dwarf system lies in a globular cluster, where the low quantity of available metals makes it difficult for planets to form. A second-generation planet, created by the heavy elements from its parent star, provides a more robust solution than the formation of a first-generation world from the metal-poor environment. Models that allow the planet to survive the evolution of both stars have been suggested, but require very tight constraints that Perets finds unlikely.

A third system with potential second-generation planets is Epsilon Reticuli, also known as HD 27442. The primary star is an orange subgiant, while the companion is a white dwarf. A Jupiter-mass planet orbits the primary, which is in the process of swelling up to be a red giant. The planet is not a strong second-generation candidate:

the distance between the white dwarf and subgiant is roughly 240 astronomical units, a bit large for producing an extended, planet-forming or planet-regrowing disk. But the pair is still close enough that HD 27442b cannot be ruled out as a second-generation planet, Perets says.

Binary systems even have the potential to create third-generation planets. If the companion star in a star–white dwarf system turns into a giant, material flowing from it could create yet another disk around the white dwarf, potentially spawning an additional generation of planets.

Evolved binary systems make up around 10% of all stellar systems, which would make second- and third-generation planets quite rare. Perets estimates that only a few percent of planets — only 1%, if extremely conservative — exist in such systems. Of the roughly 1,000 confirmed planetary systems, only a handful likely contain these phoenix planets. However, he notes that radial velocity studies tend to avoid binary systems; Kepler's exposure time for its transit detections also smeared the light curves of short-period binaries, meaning that planet hunters must use inventive analytical techniques to tease out planet signals.


NASA / JPL-CALTECH

DISKS AROUND DEAD STARS Planet-forming disks could form around old stars much as they do around young ones. This artist's illustration depicts the dust-laden disk around PSR 4U 0142+61, detected by NASA's Spitzer Space Telescope. Planets might form in this "fallback disk," which girds a star that went supernova roughly 100,000 years ago.

On the Fringe

At a time when scientists are scrambling to study and confirm the wealth of new bodies identified by Kepler and other telescopes, second-generation planets remain an object of curiosity. Although few scientists deliberately search for second-generation bodies, that doesn't mean more won't be discovered. Material shed from a star's outer layers has a higher amount of heavy elements than material in a protoplanetary disk around a young, forming star. Not only could that affect the types of planets that form, it could also lead to planets with compositions very different from those of most first-generation planets. As such, if future instruments enable scientists to identify the composition of a planet, second-generation bodies could be identified by more than just their out-of-place orbits.

Around pulsars, such detections remain a challenge. After 25 years, PSR 1257+12 remains the only non-binary pulsar confirmed to have planets orbiting it. Part of the reason may have to do with the difficulty in detecting these worlds: if the planets are small and orbit at large distances, their effect on the pulsar may be too small to measure.

Or perhaps pulsar planetary systems are just unusual. "I suspect that it's very rare to even get to the starting point where you have a circumpulsar disk with enough material to form objects," Currie says.

The ideal system, Perets says, would be a binary system separated by 30 to 40 a.u., with one star already evolved to a white dwarf. The main-sequence star would be about the mass of the Sun, while the white dwarf would have been a few times more massive before it transformed. That mass would ensure the evolving star could dump enough material into orbit around its companion to form planets.

Given these caveats, finding second-generation planets might seem like searching for the proverbial needle in a haystack. But if found, these worlds could help scientists to understand more about how first-generation planets form, too. As Hansen and Currie studied PSR 1257+12, they realized that if the planet-forming material were confined in regions known as "planet traps," it could create the system astronomers had observed. Such traps could also explain the layouts of other planetary systems.

And so even though they're peculiar and hard to find, phoenix planets might provide interesting targets in the ongoing search for planets beyond the solar system. As the rising numbers of exoplanets continue to amaze us with their variety and tenacity, these planets demonstrate that even a dying star could give birth to an alien world. ✦

*Freelance science writer **Nola Taylor Redd** loves to write about all things astronomical. She lives in rural Pennsylvania, where she homeschools her four children.*

STAR-HOPPERS

Not only can planets form from stellar debris, they can hop between stars during a binary's evolution — if they're not destroyed, that is. As the primary star loses mass, the stable orbital zones around both stars expand and merge to form a single region around the stellar duo. The planet can then jump back and forth between the two stars. Depending on how long the primary's mass loss lasts, the "safe" region might continue to encompass both stars or split into two again, trapping the planet around one star or the other.

The Very Ancient Origins of the Water Constellations

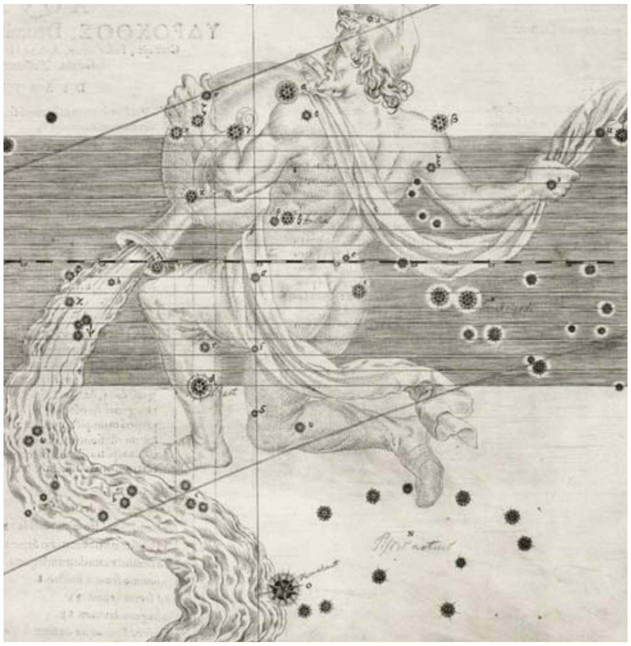
Before written history began, Capricornus was likely a goat-boat and Aquarius was a god pouring water. **Craig Crossen**

Constellations get a lot of bad press. Astronomers sometimes treat "those uncouth figures and outlines of men and monsters" (as John Herschel dismissed them in 1849) as naked-eye landmarks at best, with little else to offer the modern world. To a certain extent this is the fault of the ancient Greek and Roman mythographers, skillful raconteurs who invented elaborate yarns to explain the patterns they imagined in the stars. We know, of course, that the stars are in fact scattered almost completely randomly due to countless flukes of galactic history.

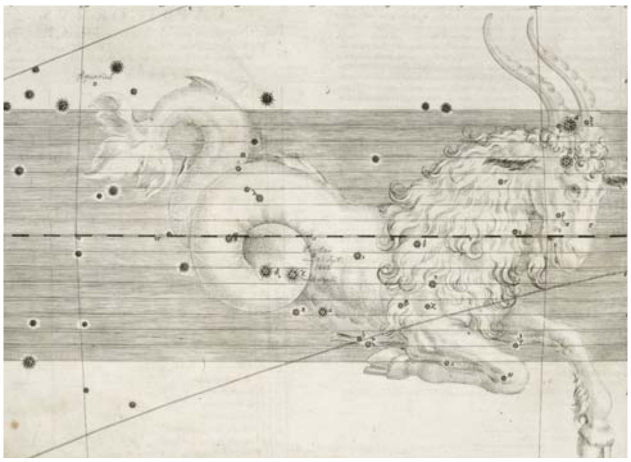
But the constellations are more than just empty *pareidolia,* like the figures and animals we see in the shapes of clouds. A cloud changes in minutes, but the patterns of the stars change very little from age to age. The constellations we know so well today trace the cultural flow of Western Civilization from its earliest known beginnings — in some cases, even from before the invention of writing some 5,000 years ago. Either in name or in form, and often in both, many can be followed from Greece and Rome back to the early civilizations of ancient Mesopotamia (modern Iraq): the Assyrians, the Babylonians, and, most ancient of all, the Sumerians. Indeed, there are good, solid literary and archaeological reasons to believe that some of today's constellations are survivals from prehistoric cultures dating from earlier than 3000 BC.

Left: Enki, the water-god of ancient Sumeria and the original for Aquarius, is carried in his boat as inscribed on an Akkadian cylinder seal. His two symbolic water streams pour from behind his back. *Facing page:* In the city of Eridu, Enki's veiled statue takes its ceremonial boat ride beneath his temple, which is portrayed here at its height. Recent painting by Balage Balogh.

The earliest known appearance of the Goat-Fish, circa 2100 BC. It is beneath the feet of Enki, who holds his usual Streaming Water Jar with its two streams. Up one stream swim three fish.



The Greco-Roman Aquarius is often assumed to be a water carrier of the time: a lowly laborer. So why is he always spilling? As the earlier Water Pourer god, he's doing what he was supposed to do.



By classical times, Capricornus had long since lost its earliest identity as a boat with a goat's-head prow. Both illustrations are from Johann Bayer's *Uranometria* star atlas, published in 1603.

To see this, we'll trace the history of a particular category of the constellations that shone in the southern skies of those ancient lands.

The Watery South

Observing guides often point out that of the 51 constellations we've inherited from the Greeks and Romans, many are "watery." Every one of these was at or below the celestial equator in ancient times. They are, counting from west to east, Capricornus the Goat-Fish, Delphinus the Dolphin, Aquarius the Water Pourer, Piscis Austrinus the Southern Fish, Pisces the (two) Fishes, Cetus the Sea-Monster, Eridanus the River, Argo the Ship, and Hydra the Water-Serpent. Parts of the last five are in the evening sky as you read this.

By contrast, not one classical constellation that was in the ancients' northern or overhead-passing sky has a "watery" theme.

Why so much wateriness in the south? All the star patterns listed above are mentioned by the Greek astronomical poet Aratos in his *Phaenomena,* written about 270 BC but based on a prose work of the same name composed a century earlier by the astronomer Eudoxos of Cnidus. So was this "celestial sea" the mythological invention of the early Greeks?

The answer is no. To see why, we need to go back to the late 19th and early 20th centuries when European scholars began to decipher the cuneiform ("wedge-shaped") writing on the tablets of baked clay that archaeologists were discovering in the ruins of ancient Mesopotamian cities. A surprising number of these tablets turned out to be astronomical. They showed that the ancient Mesopotamians divided the celestial sphere (they anticipated the Greeks in thinking of the sky as a sphere) into three parallel zones. The north was sacred to Enlil, the god of air and weather. The region that passed high overhead was sacred to the sky-god Anu, and the southern heavens were sacred to the water-god Enki. By no coincidence, surely, the only actual Great Water for these people — the Persian Gulf — lay to their south.

So right away it seemed clear that the "wateriness" of the southern stars did not originate with the Greeks but with the Mesopotamians before them. Moreover, it turned out that something like 30 of the constellations of Greece and Rome had Mesopotamian prototypes. This was especially true of the "watery" groups. For example, in Mesopotamia Hydra was a Serpent, and Piscis Austrinus (probably 1st-magnitude Fomalhaut in particular) was a Fish. Capricornus was known as a Goat-Fish, or more precisely, a Goat-Carp. Aquarius was a Water Pourer under the name "The Great Constellation," perhaps because he represented Enki's chief priest. Enki himself pours water. Even the two Fishes of Pisces were in the Mesopotamian sky, but under the title "The Tails" — presumably because the two cords from the Fishes to the Knot Star (probably our Mira, Omicron Ceti) are tied to their tails.

JOHN CURTIS, 2008 (2)

All that remains of Eridu today is the eroded platform of the temple district. The site was spared the looting that destroyed many archeological sites during the Iraq War because it does not yield tablets or cylinder seals, coveted on the black market. The city was largely abandoned around 3400 BCE before writing and cylinder seals came into use.

Mesopotamian astronomical tablets add one "watery" southern constellation to those catalogued by the Greeks: the stars of the classical Centaurus were called "The Marsh-Boar of the Cold." Wild boars roaming the vast marshes of southern Mesopotamia were as large and as feared as the lions of the region. They were sacred to the water-god Enki. A couple of cylinder-seal engravings from about 2300 BC show marsh-boars being ritually slaughtered before him.

Why a Goat-Fish?

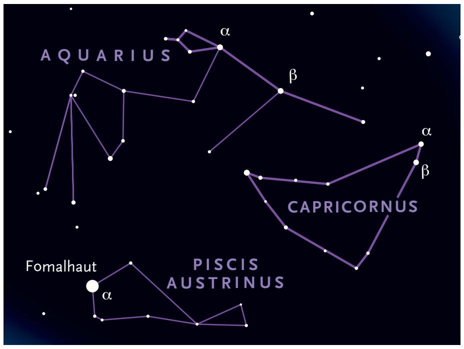
If you've ever wondered why Capricornus is such a ridiculous composite animal, here is why. Again, it's about water. The creature most often associated with Enki was always the fish, and the god's most sacred icons were the Streaming Water Jar of the Water Pourer and the Fish-Tailed Goat. The latter is first seen doing service as the footstool for the enthroned Enki on a cylinder seal engraved around 2100 BC. During the next two millennia, goat-fish appear countless times in all manner of Babylonian and Assyrian religious art.

However, the stars of Capricornus had not always been seen as a Fish-Tailed Goat. The most important Mesopotamian astronomical work that has survived to us is the *MUL.APIN* (named from its first two words, meaning "Constellation of the Plow"). It was written about 700 BC but was based upon observations made before 1000 BC. It calls the stars of Capricornus both "The Goat-Carp" and "The *Magur*-Boat," a type of boat with a highly raised stern and prow. The *Magur*-Boat must be a very old name for the star pattern — which actually does look like a boat with raised ends (which is how *Sky & Telescope*'s charts have always connected the dots, as seen on the next page). Sumerian religious texts from around 2200 BC refer to a processional *magur*-boat sacred to Enki and say that this boat had a goat's-head prow. So the stars of Capricornus were originally a *boat* with a goat's head on the front, and apparently around 2100 BC the boat morphed into a goat-headed fish. This would have been an easy, even a natural transition aesthetically, involving no religious dislocation because all the symbols involved — fish, boat, and goat — were already sacred to Enki.

Eridanus from Eridu

Unfortunately, none of the Assyrian, Babylonian, or Sumerian astronomical texts that have survived clue us in on what the Mesopotamians saw in the stars of the classical Cetus, Eridanus, and Argo. Cetus and Argo seem to have been early Greek or late Mycenaean innovations formed sometime around 1000 BCE, either from scratch or from predecessors unknown. But today's Eridanus the River may be the remains of something older even than Capricornus.

Babylonian and Assyrian texts call Alpha Carinae, the classical Canopus, "Star of [the city] of Eridu." Eridu, located on the Euphrates River, was the most southerly of the ancient cities of Mesopotamia, and its patron deity was Enki. The city was near the river's mouth on the Persian Gulf. (Silting has caused the mouth of the Euphrates to migrate far south since then.) According to the Sumerians' own myths, their civilization began at Eridu. Indeed, archaeological excavations in the late 1940s at the site (now only a plateau of sand and decayed brick in a desert waste) confirmed Eridu's great antiquity. Archaeologists unearthed layers of superimposed ruined temples going back to about 4700 BC. Some 18 distinct layers were catalogued. No inscriptions were found in the earliest temples for the simple reason that when they were built and used, writing had not yet been invented. But the huge quanti-



The Water Pourer with two streams from his jar, the Fish below the streams, and the Boat under his feet seen as *Sky & Telescope* connects the dots.

ties of burnt fish bones found within them indicated that Enki was already being worshipped there.

An even more surprising discovery was that Eridu's inhabitants abandoned it as a living city by 3400 BC, still before the invention of writing. The apparent cause was that the Euphrates suddenly changed course due to silting, leaving the city and its surrounding area without fresh water.

So the cult of Enki, and the god's sacred iconography, must have been pretty well established before 3400 BC. Ancient Mesopotamian religion was extremely well conserved from millennium to millennium — as is demonstrated by the fact that, even though Eridu was abandoned by 3400 BC, pious Mesopotamian monarchs continued to restore and rebuild its temples for another 3,000 years. This implies that the icons of Enki later known as constellations — the Fish, the Streaming Water Jar, and the *Magur*-Boat — were probably constellations before 3400 BC.

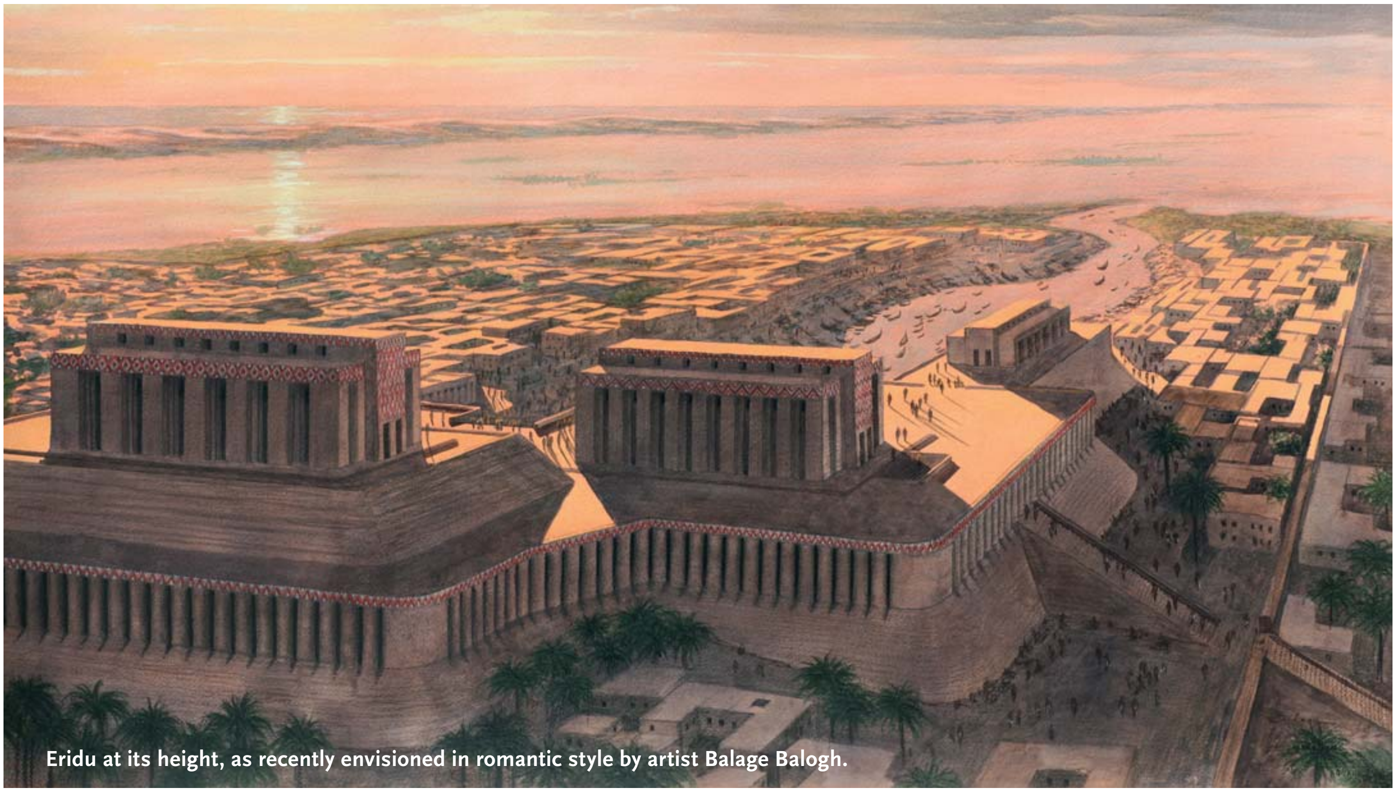
But what about Eridanus the River? Did it have a Mesopotamian prototype? The answer seems to be yes.

The key lies in the Sumerian name for Canopus: ^{mul}NUN^{ki}, "Star of Eridu." (The star currently named "Nunki," Sigma Sagittarii, had the name misapplied to it in the 19th century.) Some later, classical sources indicate that Eridanus ended at Canopus, rather than at Achernar as in today's version of the constellation. In its heyday, the city of Eridu was near the Euphrates' mouth. This suggests that the Greeks' celestial River originated in Mesopotamia and represented the Euphrates. The very name Eridanus, some scholars have pointed out, is phonetically similar to Eridu. "Eridanus," then, would have been the "River of Eridu."

So given the fact that the city was abandoned before written history begins, this constellation seems to be literally prehistoric.

Thus the "watery" constellations of our southern skies seem to preserve not only the early Greeks' heavy cultural indebtedness to the Assyrians, Babylonians, and Sumerians, they even hint of the very beginnings of that civilization — and thus of Western Civilization itself — in the marshes of far southern Mesopotamia. ✦

***Craig Crossen** has researched the history of constellations and star names for more than a third of a century on three continents. He is currently completing books on the history of the classical constellations and on the history of archaeology in Iraq, and has begun a literary study of T. E. Lawrence.*



Eridu at its height, as recently envisioned in romantic style by artist Balage Balogh.

The Milky Way Galaxy paints the sky above the ALMA array, Chile.

In This Section

Additional Observing Stories:

PHOTOGRAPH: ESO / BABAK TAFRESHI

Sky at a Glance

MARCH 2015

2 **ALL NIGHT:** The waxing gibbous Moon shines near Jupiter.

8 **DAYLIGHT-SAVING TIME STARTS** at 2 a.m. for most of the United States and Canada.

8–23 **DUSK:** Observers at mid-northern latitudes may be able to view the zodiacal light during evening twilight; at this time of year it stands especially high. Look to the west about 80 minutes after sunset for a tall pyramid of diffuse light, sloping to the left along the path of the ecliptic.

9 **AFTER MIDNIGHT:** Algol shines at minimum brightness for roughly two hours centered at 3:13 a.m. EDT (12:13 a.m. PDT); see page 51.

11–12 **LATE NIGHT:** Algol shines at minimum brightness for roughly two hours centered at 12:02 a.m. EDT.

12 **BEFORE DAWN:** The Moon, not quite last-quarter, is about 3° from Saturn and 9° above Antares.

20 **SPRING BEGINS** in the Northern Hemisphere at the equinox, 6:45 p.m. EDT (3:45 p.m. PDT).

21 **DUSK:** A waxing crescent Moon shines less than 3° from Mars. Look for them below Venus.

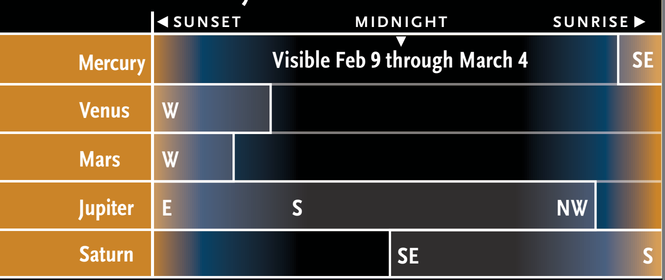
22 **DUSK:** The crescent Moon shares the early evening with Venus, shining about 4° from the bright planet on the western horizon.

24 **EVENING:** The Moon crosses the Hyades; it occults Aldebaran for observers in Alaska and northwestern Canada.

29 **MORNING:** Algol shines at minimum brightness for roughly two hours centered at 4:58 a.m. EDT.

Planet Visibility

SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH



Moon Phases

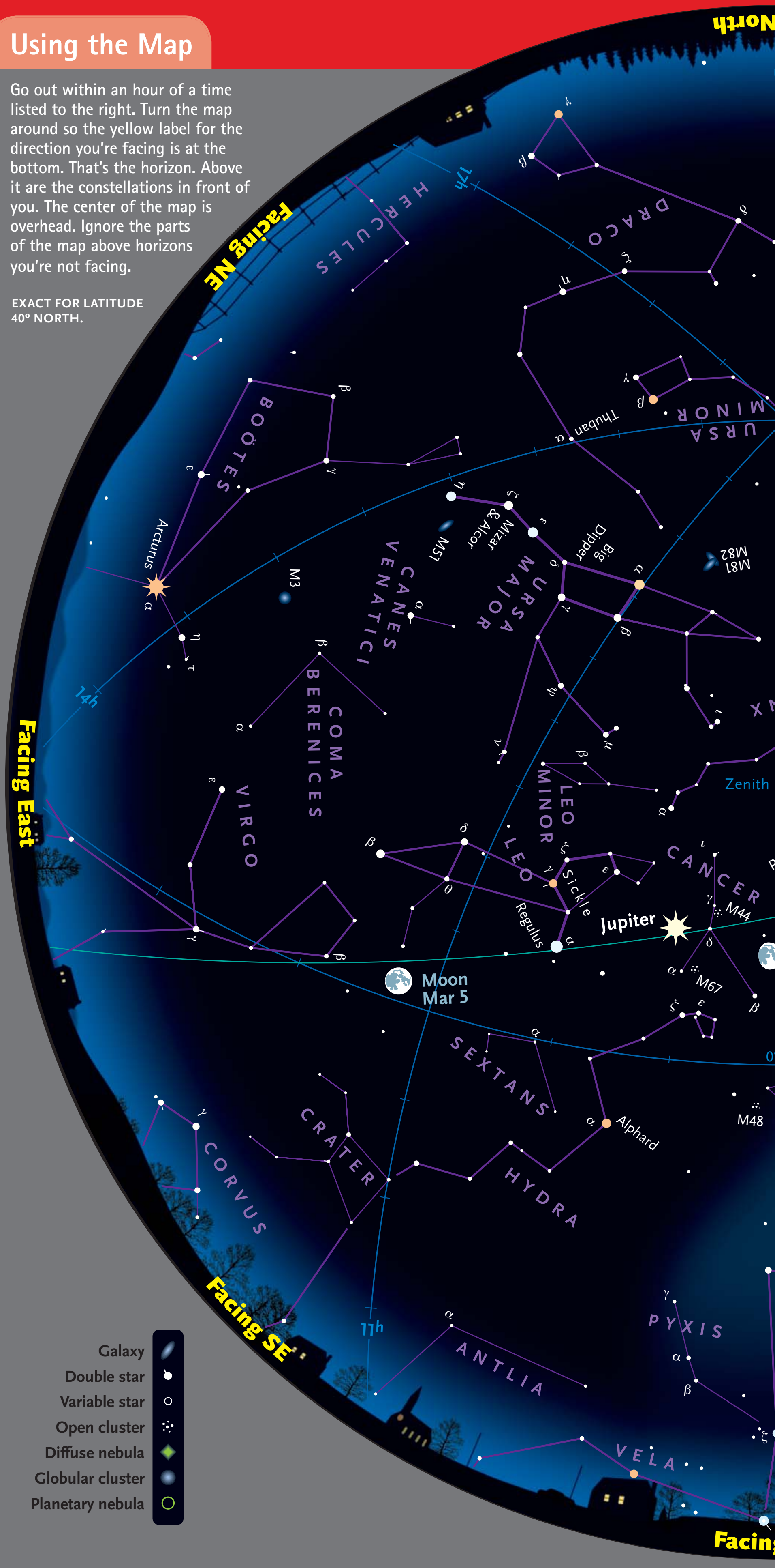
Full March 5 1:05 p.m. EST	Last Qtr March 13 1:48 p.m. EDT
New March 20 5:36 a.m. EDT	First Qtr March 27 3:43 a.m. EDT

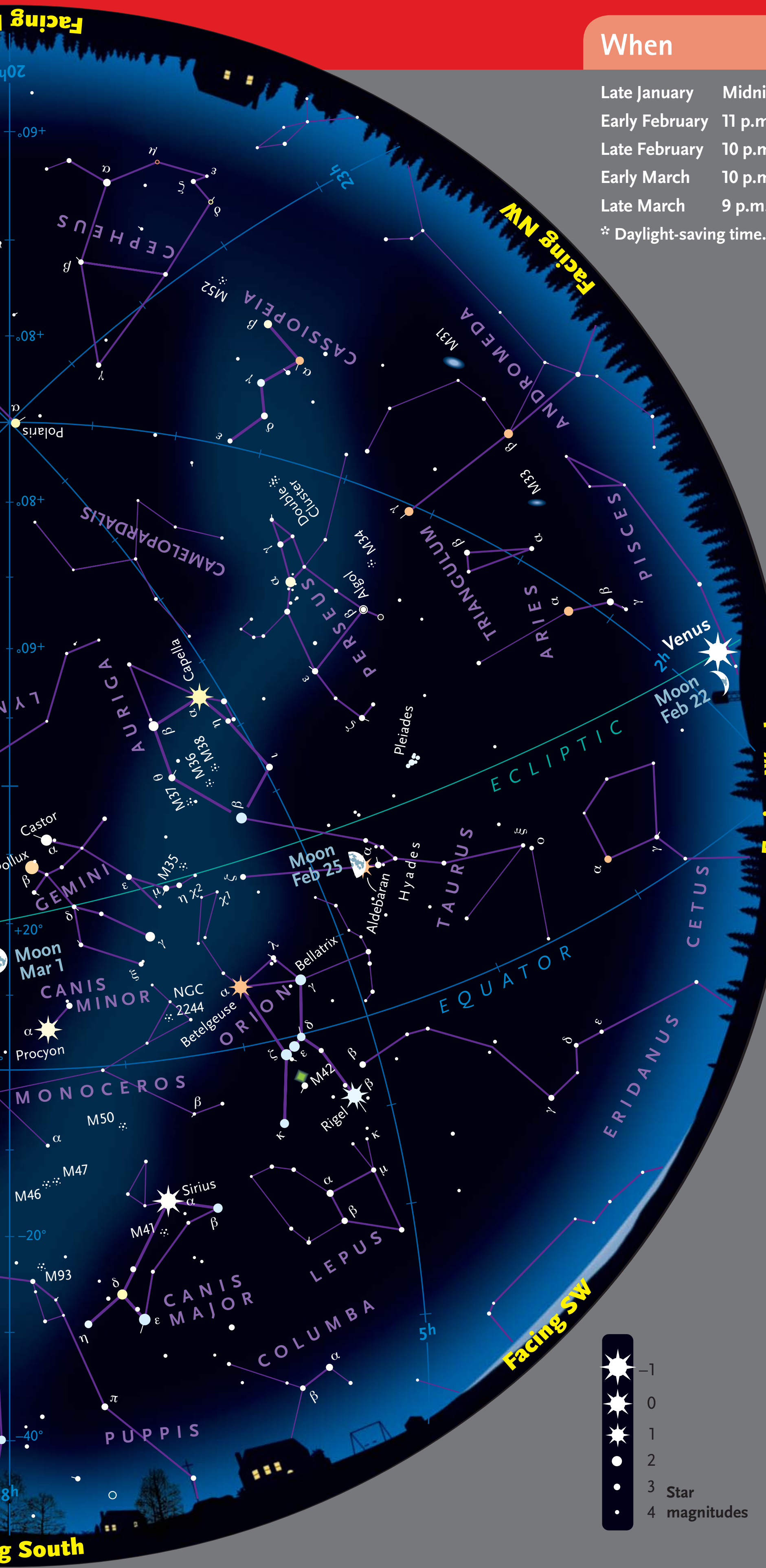
SUN	MON	TUE	WED	THU	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

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

* Daylight-saving time.

Gary Seronik

Binocular Highlight

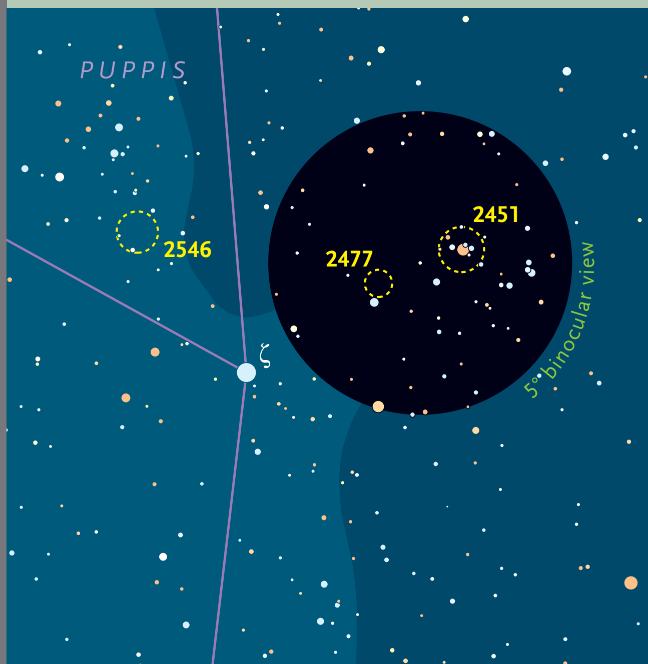
A Trio of Puppis Clusters

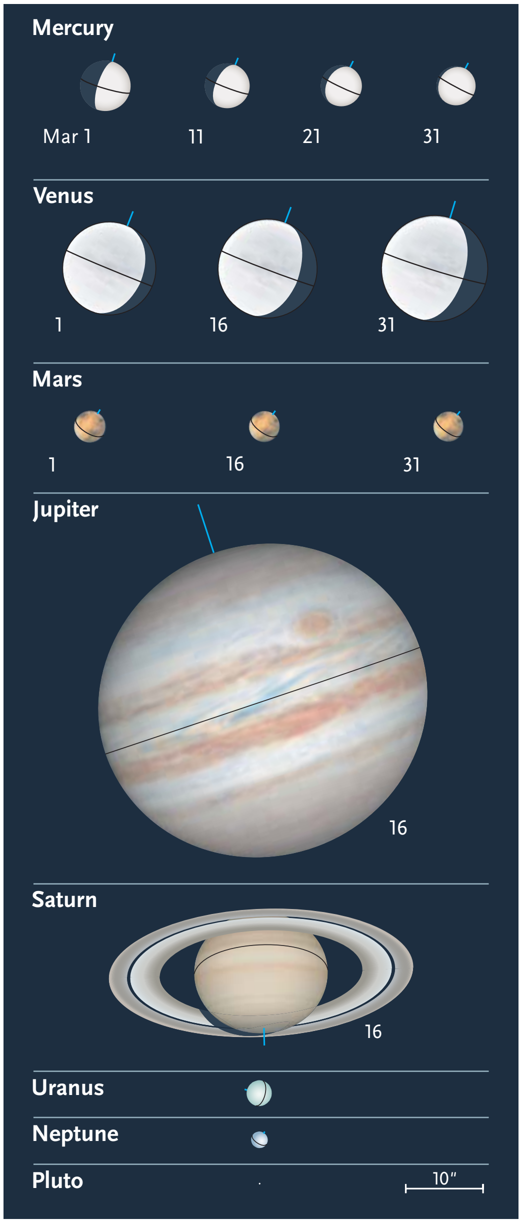
The swath of Milky Way running south through Canis Major and into Puppis is rich with open clusters — some well known, some not. Situated near 2.2-magnitude Zeta (ζ) Puppis is a trio of fine binocular targets. However, you'll need an unobstructed southern horizon to claim them.

Let's begin west of Zeta with the splashiest cluster of the three, **NGC 2451**. It's a loose collection of more than a dozen stars scattered across about one degree of sky. Several curving rows of stars seem to emanate from a single, 3.6-magnitude sun near the cluster's center. In my 10×50 binoculars, it almost looks like a child's connect-the-dots rendering of a face-on spiral galaxy.

Just to the east, and in the same binocular field as NGC 2451, lies **NGC 2477**. The two clusters are a study in contrasts. Whereas NGC 2451 is a ragged assemblage dotted with several bright stars, NGC 2477 is a rich, compact round glow. But with careful viewing in my 10×50s, I can see that it's neither perfectly round nor uniformly lit — a few individual stars occasionally wink in and out of view. NGC 2477 is a prominent object under dark skies, though it likely won't survive light-polluted conditions as well as its showy neighbor.

Last (and arguably least), jump east of Zeta to locate **NGC 2546**. In my 10×50s, this cluster looks like a detached clump of Milky Way. It's somewhat elongated along its north-south axis, and I can make out a dozen or so individual cluster stars. NGC 2546 isn't a particularly stunning find, but since you're in the neighborhood anyway, why not have a look? ✦



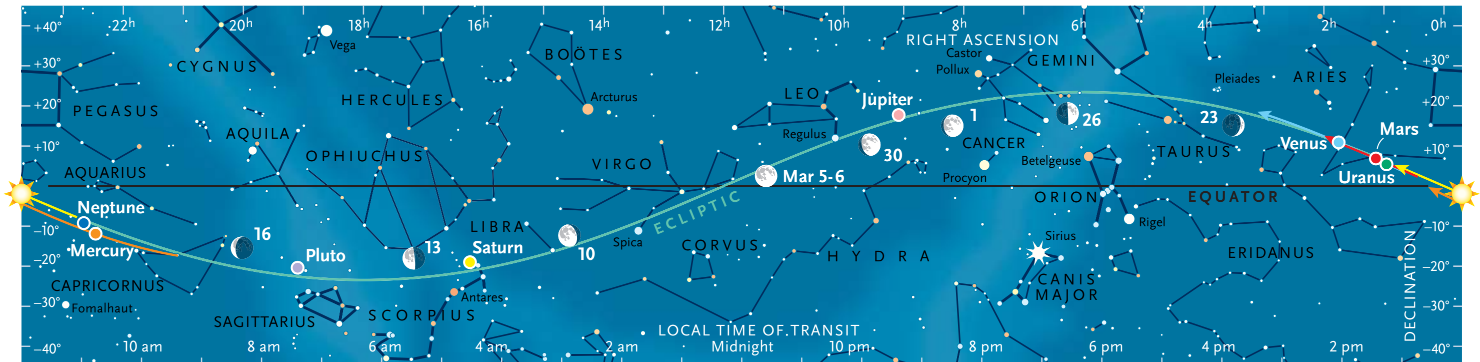


Sun and Planets, March 2015

	March	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	22h 45.6m	–7° 52′	—	–26.8	32′ 17″	—	0.991
	31	0h 35.8m	+3° 52′	—	–26.8	32′ 02″	—	0.999
Mercury	1	21h 04.7m	–17° 27′	26° Mo	0.0	6.5″	65%	1.028
	11	21h 58.0m	–14° 21′	23° Mo	–0.1	5.8″	77%	1.159
	21	22h 57.4m	–9° 08′	18° Mo	–0.4	5.3″	86%	1.263
	31	0h 01.9m	–1° 58′	10° Mo	–1.0	5.0″	95%	1.331
Venus	1	0h 37.2m	+3° 14′	30° Ev	–3.9	12.0″	86%	1.384
	11	1h 21.8m	+8° 21′	32° Ev	–3.9	12.5″	84%	1.332
	21	2h 07.0m	+13° 09′	34° Ev	–4.0	13.1″	81%	1.275
	31	2h 53.3m	+17° 27′	36° Ev	–4.0	13.7″	78%	1.214
Mars	1	0h 25.3m	+2° 12′	27° Ev	+1.3	4.2″	97%	2.235
	16	1h 07.1m	+6° 48′	23° Ev	+1.3	4.1″	98%	2.298
	31	1h 49.1m	+11° 05′	20° Ev	+1.4	4.0″	99%	2.358
Jupiter	1	9h 09.6m	+17° 23′	155° Ev	–2.5	44.5″	100%	4.426
	31	9h 01.0m	+17° 59′	123° Ev	–2.3	41.6″	99%	4.741
Saturn	1	16h 12.0m	–19° 02′	95° Mo	+0.4	16.9″	100%	9.824
	31	16h 11.7m	–18° 56′	125° Mo	+0.3	17.8″	100%	9.360
Uranus	16	0h 56.3m	+5° 21′	20° Ev	+5.9	3.4″	100%	20.931
Neptune	16	22h 38.7m	–9° 21′	17° Mo	+8.0	2.2″	100%	30.916
Pluto	16	19h 04.4m	–20° 31′	70° Mo	+14.2	0.1″	100%	33.165

The table above gives each object's right ascension and declination (equinox 2000.0) at 0h Universal Time on selected dates, and its elongation from the Sun in the morning (Mo) or evening (Ev) sky. Next are the visual magnitude and equatorial diameter. (Saturn's ring extent is 2.27 times its equatorial diameter.) Last are the percentage of 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-March; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side). "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

A Swarm of Stars

The Beehive brightens a dim stretch of the night sky.

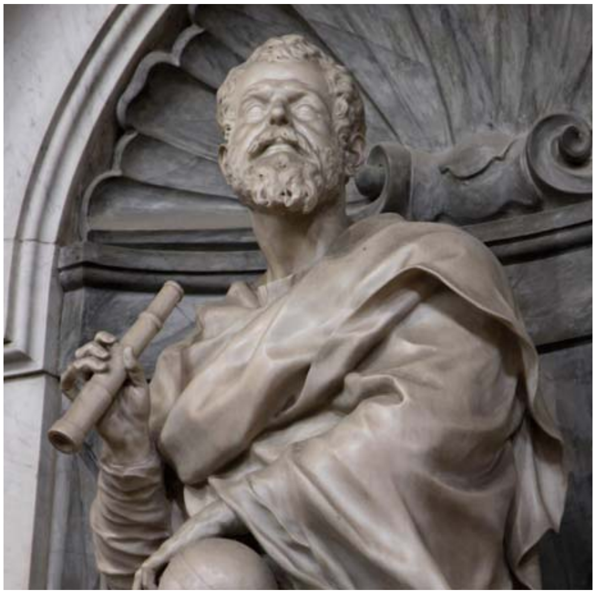
What is the only constellation whose brightest member is not a star but instead a Messier object? Cancer the Crab. Its 3.1-magnitude Messier object is the great star cluster of early spring, M44, better known as the Beehive.

How important a celestial object is M44? Cancer has been called "the empty space" between Gemini and Leo. In his book *The Messier Objects*, Steve O'Meara writes, "if it weren't for the mystifying cloudy appearance of open cluster M44, which draws your gaze to the surrounding 4th-magnitude stars, it is conceivable that dim Cancer might have either gone unnoticed by ancient stargazers or have been envisioned differently."

The Mystifying Patch of Glow in the Dark Trench. There's a long, dark north-to-south (really slightly northwest-to-southeast) slice of heavens between the final bright constellations of winter and the spring bright beasts of Leo and Ursa Major. On March evenings, it starts overhead in the high north with dim Camelopardalis and Lynx. This darker region of sky stretches south through Cancer, Sextans, and western Hydra to Antlia the Air Pump. Astronomy writer Guy Ottewell calls this feebly-lit sweep of sky "the Dark Trench," and author and editor Terence Dickinson has referred to at least part of the region as "the Hydra Void." The Dark Trench is especially prominent because the sky just west of it burns with such luminaries as Capella, Pollux and Castor, Procyon, and Sirius.

There are only three sights in the Dark Trench conspicuous to your unaided eyes — if your light pollution is minimal. Working north along a relatively short line, the sights are: the 2nd-magnitude heart of Hydra, Alpha (α) Hydrae (better known as Alphard — a name which means "the lonely"); the faint but compact and shapely head of Hydra; and a patch of glow well over a degree wide — M44, the Beehive Star Cluster.

Manger in the Middle. To the best of my knowledge, no one knows who first called M44 "the Beehive." A look through a telescope at low magnification shows that the open cluster indeed takes an elliptical or rectangular form that includes a swarm of many stars of similar brightness, either paired or bunched together. But in ancient Roman times, M44 was pictured as a quite different object, a Praesepe, or "manger." What animals were imagined to be eating at this manger? That would be the north-to-south pair of stars just east of M44, Delta (δ) and Gamma (γ) Cancri — Asellus Australis and Asellus Borealis, the Southern and Northern Donkeys. M44 is positioned just west of the midway point between these two stars.



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Galileo Galilei was the first to observe the Beehive Cluster with a telescope. He described the view in his 1610 *Sidereus nuncius*.

This isn't the only case of the manger resting in the middle, however. M44 stands almost dead center within the ancient pattern of Cancer, and near the middle of the area of sky cordoned off by the lines of the modern Cancer. More importantly, M44 lies almost halfway between Gemini's Pollux and Leo's Regulus. Finally, M44 is almost in the middle of the road of the zodiac, just north of the ecliptic — and therefore in the way of the traffic of Sun, Moon, and planets.

Target Beehive. M44 makes a sizable target for the Moon and planets. Planets can take a day or two to pass through the cluster, sometimes even longer. Long ago, I enjoyed a passage of the highly reflective asteroid Nysa through M44 — by an interesting coincidence, asteroid 44. But to me the most interesting object to pass near the Beehive did so in May 1983. That was Comet IRAS-Araki-Alcock, which, on the evening it was near the Beehive, came closer to Earth than any comet had in more than 200 years. The comet looked like an even bigger M44 and, for one night, shined as bright as 1st magnitude. ✦

Venus Rises, Mars Lowers

Venus and Jupiter move higher as Mars sinks from view.

In March, everyone at mid-northern latitudes gets to see very bright Venus in the west for a few hours after sunset. Rather dim Mars is visible below Venus more briefly. Bright Jupiter is almost at its highest in the south around the time Venus sets in mid-evening. Saturn rises in the middle of the night and shines at its highest around morning twilight.

The most majestic planetary progression to observe this spring, though, is the closing of the huge gap between Venus and Jupiter. They're still far apart this month, but by late June, these two brightest planets will move into a very close and prolonged conjunction in the evening sky.

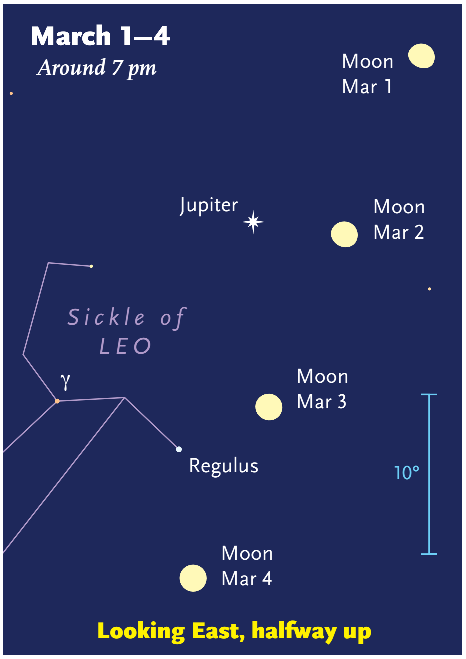
DUSK & EARLY EVENING

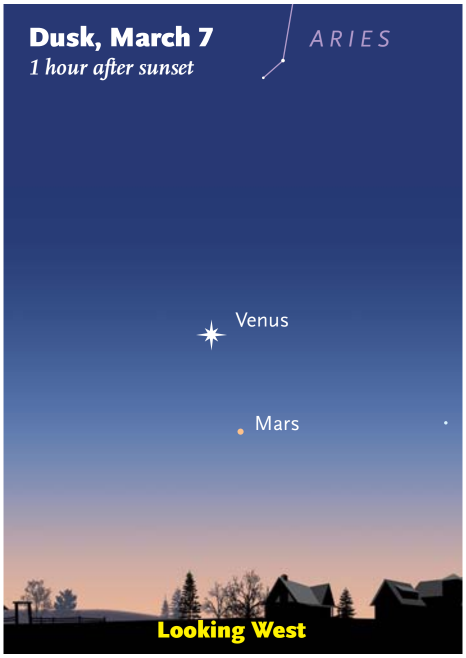
Venus glows prominently in the west, appearing slightly higher with each nightfall. For observers around latitude 40° north, the interval between sunset and Venus-set increases from about 2½ to slightly more than 3 hours. That means it's bright and obvious low in the west for at least an hour after complete dark hours. Venus remains shining at magnitude –4.0 throughout March. Telescopes show its diameter increasing slightly from 12″ to 14″ wide while its gibbous phase wanes from 86% to 78% sunlit.

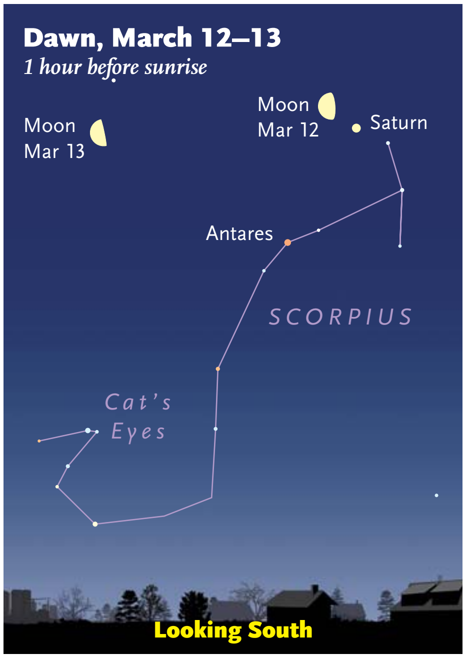
Mars glimmers dimly about 4° below Venus as the month begins, but the gap between them increases significantly each week as Mars sinks lower into the twilight. By the end of March they're 17° apart. An observer around latitude 40° north will see Venus's apparent altitude increasing to more than 20° in March when viewed about an hour after sunset. During the same period, Mars descends to about 5° high. By month's end, Mars sets only about 1½ hours after the Sun and shines at a weak magnitude +1.4, suffering from atmospheric extinction to boot. In telescopes, the Red Planet appears only 4.0″ wide, hardly larger than a star.

But Venus and Mars keep very close company with another planet. Much dimmer **Uranus** is nearest to Venus on March 4th. This is the closest planet-planet conjunction of 2015. At around 20^h UT (3 p.m. EST), Venus passes just 0.09° north-northeast of Uranus, which at magnitude +5.9 is fainter by almost exactly 10 magnitudes, or 10,000 times. At nightfall in the Eastern time zone, use optical aid to look for Uranus 0.3° below Venus. It's 0.5° below Venus at dusk in the Pacific time zone three hours later.

Around that time, Venus, Uranus, and Mars form a "trio" of planets within a circle just under 5° across. At around 19^h UT on March 11th, Mars passes just 0.27° north-northwest of Uranus. By late twilight in North America, look for Uranus about 0.4° below or lower right of Mars. Telescopes at moderately high magnification can show the tiny-looking globes of the two worlds in



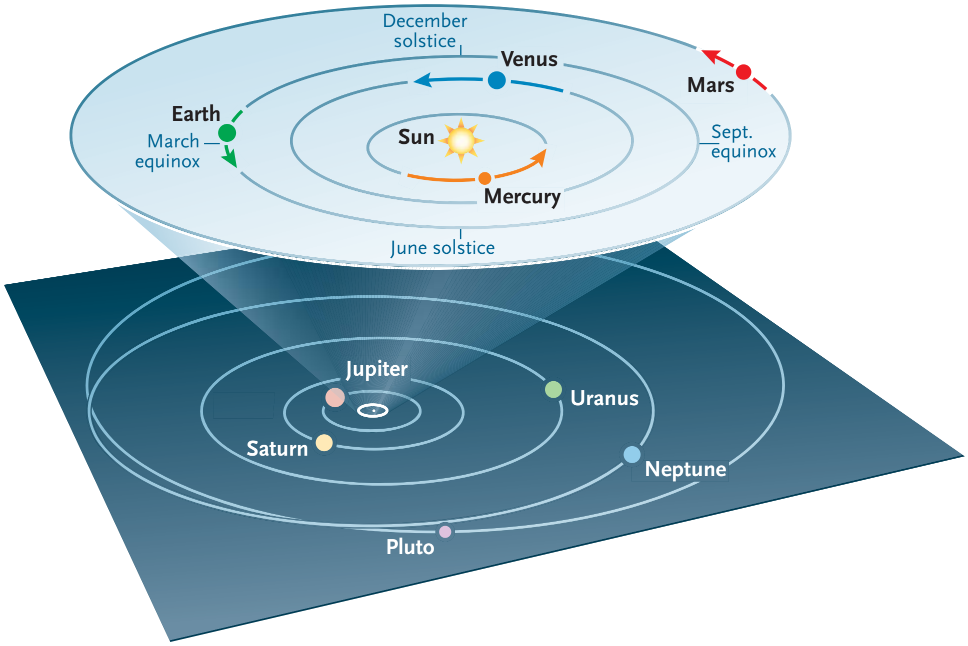




Fred Schaaf

ORBITS OF THE PLANETS

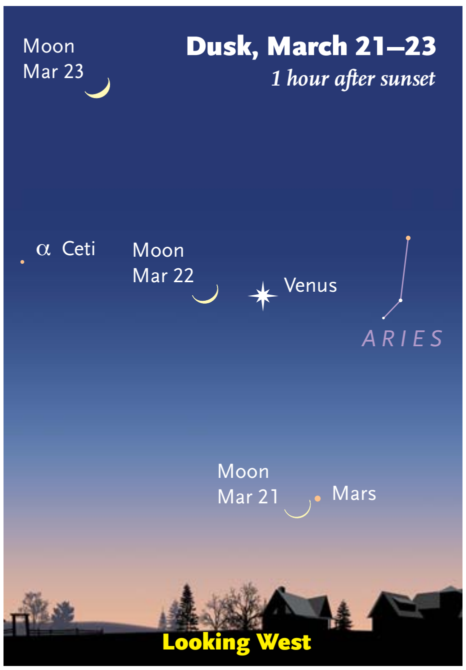
The curved arrows show each planet's movement during March. The outer planets don't change position enough in a month to notice at this scale.



the same field of view — Mars 4.1″ across and Uranus 3.4″ — even though Uranus is currently nine times farther away.

DUSK TO NEAR DAWN

Jupiter looks impressive in March, having passed opposition on February 6th. Look for it roughly halfway up the eastern sky at nightfall as the month begins. That's already high enough to get fine telescopic views of the planet's plethora of cloud features. Jupiter is even higher when it transits the meridian around 10 or 11 p.m. standard time at the start of March, and soon after twilight at month's end. It fades a bit (from magnitude –2.5 to –2.3) and its apparent diameter decreases a bit (from 44″ to 41″) over the course of the month. The yellow-white world retrogrades westward by a few degrees in eastern Cancer, but will not get very close to M44, the Beehive Cluster, before halting and resuming direct (eastward) motion in April.



MIDNIGHT TO DAWN

Saturn rises around the midnight hour. Over the course of the month, it brightens from magnitude +0.4 to +0.3, and the width of its globe increases from 17″ to almost 18″ across. The ringed planet shows itself highest in the south around the start of morning twilight, the best time to get a view of its luxuriously open rings. Saturn halts its direct (eastward) motion on March 14th before starting to retrograde, so it appears to linger all month just above Nu (ν) Scorpii (Jabbah) in the head of the Scorpion.

DAWN

Mercury sinks low in the sunrise glow in March after its somewhat mediocre showing in late February. For observers at mid-northern latitudes, the planet is visible, low in the east in bright morning twilight, during the first part of March.

Neptune was in conjunction with the Sun on February 26th, so remains too low in the dawn sky to be visible this month.

SUN & MOON

The **Sun** is totally eclipsed for viewers in parts of the North Atlantic and Arctic Oceans on March 20th. Partial phases will sweep across all of Europe, North Africa, and central Asia; see full details at **solar eclipse2015.org.uk**. Coincidentally, just over 12 hours later, at 6:45 p.m. EDT on the 20th, the Sun reaches the March equinox. The Sun's northward equator crossing initiates spring in the Northern Hemisphere and autumn in the Southern Hemisphere.

The waxing gibbous **Moon** hangs well to the right of Jupiter on the evening of March 2nd and well to the upper right of Regulus the next evening. The waning gibbous Moon is less than 3° upper left of Saturn at dawn on March 12th for North America, with Antares down below them. At dusk on March 21st, the waxing crescent Moon can be found less than 2° to the lower left of Mars; the next night, March 22, it comes within 4° of Venus — a dramatic pairing. A thicker lunar crescent shines high among the Hyades on March 24th, and occults Aldebaran as seen from much of Alaska.

The waxing gibbous Moon is well right of Jupiter again on March 29th, and then in the vicinity of Regulus on the final two nights of the month. ✦

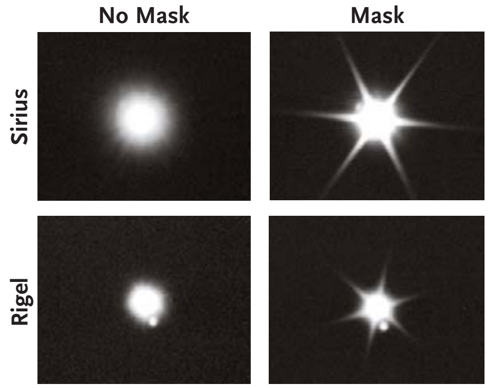
Trying for Sirius B

The nearest, most famous white dwarf is a bit less difficult every year.

Not since 1979 has Sirius B, the legendary white-dwarf companion of Sirius A, been as detectable in amateur telescopes as it is now. It's 10.7 arcseconds from the primary star this winter, just short of the maximum separation of 11.3″ that it will reach in 2022. So if you've tried and failed to resolve Sirius B in the past, maybe it's time to try again.

Sirius shines highest in the south around 10 p.m. local time at the beginning of February, around 8 p.m. at the beginning of March, and in late twilight by the end of March. A little twilight may help matters. The challenge in spotting Sirius B isn't its faintness (at magnitude 8.5) but the overwhelming glare of Sirius A, 10,000 times brighter at magnitude –1.5. A bright sky suppresses glare effects, as telescopic observers of dazzling Venus have always appreciated.

The place to look is east of Sirius A and just a bit north (at position angle 282°).



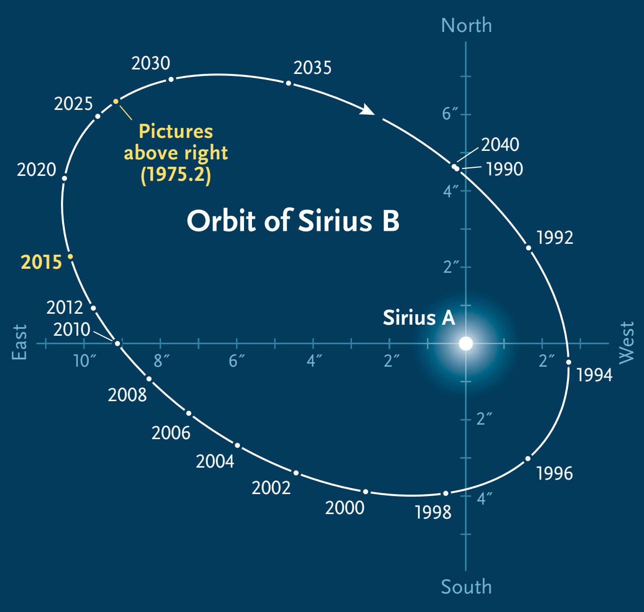
Left: Using a 14-inch reflector, John Hothersall took this stacked-video image on January 17, 2011, from Australia where Sirius passes overhead. The blue "Pup" of the Dog Star shows distinctly here even though it lies on the eastern diffraction spike of Sirius A. "Visually I got the best results using a blue filter," he writes, "as the B component is a little bluer than the bright A component, cutting the glare ever so slightly." *Right:* When Sirius and its companion were 11.3″ apart in 1975, Dennis di Cicco used a 14-inch Schmidt-Cassegrain scope with and without a hexagonal mask to take these photos of Sirius and Rigel. Only with the mask is Sirius B really apparent, just northeast (upper left) of brilliant A.

Crucial factors are the atmospheric seeing, which sometimes steadies for a while in twilight, and of course the telescope's aperture; the larger the aperture the more compact a spot of light Sirius B should be concentrated into, making it stand out better. Also a factor is the smoothness of your telescope's optics. A "rough" (micro-ripply or dog-biscuity) surface on a telescope mirror scatters light and reduces contrast even if the mirror's large-scale figure is perfect. (This problem can result from inadequate hand-finishing.)

In addition to waiting for good seeing, other tips are to use very high power, put an occulting bar in your eyepiece so you can hide Sirius A behind it (tape aluminum foil across half of the eyepiece's field stop), and put a square or hexagonal mask over the front of the telescope to herd the aperture's diffraction away from Sirius B, as in the illustration above.

Don't be fooled by faint ghost images of Sirius itself, caused by reflections between lens elements in the eyepiece. Check this by moving Sirius around the field of view; a ghost image will change position with respect to the bright star at least slightly.

The apparent orbit of Sirius B with respect to Sirius A, as projected onto the plane of the sky. The true orbit is inclined 43° to the sky. Dates without decimals are for the beginning of the year. The two stars orbit each other in 50.09 years, during which they range from 8 to 31 a.u. apart.



Alan MacRobert

You can practice on Rigel, a similarly wide double star but with a brightness difference of 1,000 times rather than 10,000. For more about observing Sirius B see the September 2013 issue, page 30.

Extreme of the Extreme

Sirius B is not only the closest white dwarf (at 8.6 light-years) but also one of the more massive, and therefore one of the smallest, densest, and most extreme. According to a 2005 study using the Hubble Space Telescope, Sirius B contains 0.98 of a solar mass, well over the usual white-dwarf mass of about 0.6. Its extra-intense gravity compresses it into an unusually small size for a white dwarf: a diameter of 11,700 km (7,300 miles), slightly smaller than Earth. This gives it an unusually high surface gravity of 380,000 gs and an average density of 2.3 metric tons per cubic centimeter.

By comparison, the only white dwarf in the sky that's easy for amateurs to spot is Omicron[2] Eridani B (40 Eridani B), as told in last December's issue, page 50. It has a more typical mass of 0.50 Sun, enough to compress it only to 1.6 times Sirius B's diameter — considerably larger than Earth. Its surface gravity is thus only a fifth as great as that of Sirius B, and its average density is only an eighth as great.

But it's still a white dwarf, and if you can't detect Sirius B, 40 Eridani B is no small consolation prize. It's still high in the south to southwest at nightfall in early February and March.

Minima of Algol

Feb.	UT	Mar.	UT
2	21:20	3	13:34
5	18:10	6	10:24
8	14:59	9	7:13
11	11:49	12	4:02
14	8:38	15	0:52
17	5:27	17	21:41
20	2:17	20	18:30
22	23:06	23	15:20
25	19:56	26	12:09
28	16:45	29	8:58

These geocentric predictions are from the heliocentric elements Min. = JD 2452253.559 + 2.867362*E*, where *E* is any integer. Courtesy Gerry Samolyk (AAVSO). For a comparison-star chart and more info, see SkyandTelescope.com/algol.

Phenomena of Jupiter's Moons, March 2015

Mar. 1	10:50	I.Oc.D
	13:42	I.Ec.R
Mar. 2	8:00	I.Tr.I
	8:33	I.Sh.I
	10:17	I.Tr.E
	10:51	I.Sh.E
	12:40	II.Oc.D
	16:41	II.Ec.R
	22:46	III.Tr.I
Mar. 3	1:05	III.Sh.I
	2:23	III.Tr.E
	4:44	III.Sh.E
	5:17	I.Oc.D
	8:10	I.Ec.R
Mar. 4	2:26	I.Tr.I
	3:02	I.Sh.I
	4:43	I.Tr.E
	5:19	I.Sh.E
	7:35	II.Tr.I
	8:49	II.Sh.I
	10:29	II.Tr.E
	11:43	II.Sh.E
	23:43	I.Oc.D
Mar. 5	2:39	I.Ec.R
	20:52	I.Tr.I
	21:30	I.Sh.I
	23:10	I.Tr.E
	23:48	I.Sh.E
Mar. 6	1:48	II.Oc.D
	5:58	II.Ec.R
	12:28	III.Oc.D
	16:36	IV.Oc.D
	18:10	I.Oc.D
	18:48	III.Ec.R
	21:08	I.Ec.R
	21:25	IV.Oc.R
	22:53	IV.Ec.D
Mar. 7	3:45	IV.Ec.R
	15:19	I.Tr.I
	15:59	I.Sh.I
	17:36	I.Tr.E
	18:16	I.Sh.E
	20:45	II.Tr.I
	22:08	II.Sh.I
	23:39	II.Tr.E
Mar. 8	1:02	II.Sh.E
	12:36	I.Oc.D
	15:37	I.Ec.R
Mar. 9	9:45	I.Tr.I
	10:28	I.Sh.I
	12:03	I.Tr.E
	12:45	I.Sh.E
	14:57	II.Oc.D
	19:15	II.Ec.R
Mar. 10	2:10	III.Tr.I
	5:05	III.Sh.I
	5:47	III.Tr.E
	7:03	I.Oc.D
	8:43	III.Sh.E
	10:05	I.Ec.R
Mar. 11	4:12	I.Tr.I
	4:56	I.Sh.I
	6:29	I.Tr.E
	7:14	I.Sh.E
	9:54	II.Tr.I
	11:26	II.Sh.I
	12:48	II.Tr.E
	14:20	II.Sh.E
Mar. 12	1:30	I.Oc.D
	4:34	I.Ec.R
	22:39	I.Tr.I
	23:25	I.Sh.I
Mar. 13	0:56	I.Tr.E
	1:42	I.Sh.E
	4:06	II.Oc.D
	8:33	II.Ec.R
	15:53	III.Oc.D
	19:56	I.Oc.D
	22:47	III.Ec.R
	23:03	I.Ec.R
Mar. 14	17:05	I.Tr.I
	17:53	I.Sh.I
	19:22	I.Tr.E
	20:11	I.Sh.E
	23:05	II.Tr.I
Mar. 15	0:44	II.Sh.I
	1:31	IV.Tr.I
	1:59	II.Tr.E
	3:38	II.Sh.E
	6:16	IV.Tr.E
	9:12	IV.Sh.I
	13:58	IV.Sh.E
	14:23	I.Oc.D
	17:32	I.Ec.R
Mar. 16	11:32	I.Tr.I
	12:22	I.Sh.I
	13:49	I.Tr.E
	14:39	I.Sh.E
	17:16	II.Oc.D
	21:51	II.Ec.R
Mar. 17	5:37	III.Tr.I
	8:50	I.Oc.D
	9:04	III.Sh.I
	9:14	III.Tr.E
	12:00	I.Ec.R
	12:42	III.Sh.E
Mar. 18	5:59	I.Tr.I
	6:51	I.Sh.I
	8:16	I.Tr.E
	9:08	I.Sh.E
	12:16	II.Tr.I
	14:02	II.Sh.I
	15:09	II.Tr.E
	16:56	II.Sh.E
Mar. 19	3:17	I.Oc.D
	6:29	I.Ec.R
Mar. 20	0:26	I.Tr.I
	1:19	I.Sh.I
	2:43	I.Tr.E
	3:37	I.Sh.E
	6:26	II.Oc.D
	11:08	II.Ec.R
	19:22	III.Oc.D
	21:44	I.Oc.D
	23:02	III.Oc.R
	23:07	III.Ec.D
Mar. 21	0:58	I.Ec.R
	2:47	III.Ec.R
	18:53	I.Tr.I
	19:48	I.Sh.I
	21:10	I.Tr.E
	22:05	I.Sh.E
Mar. 22	1:28	II.Tr.I
	3:21	II.Sh.I
	4:21	II.Tr.E
	6:14	II.Sh.E
	16:11	I.Oc.D
	19:26	I.Ec.R
Mar. 23	7:44	IV.Oc.D
	12:36	IV.Oc.R
	13:20	I.Tr.I
	14:17	I.Sh.I
	15:37	I.Tr.E
	16:34	I.Sh.E
	16:56	IV.Ec.D
	19:37	II.Oc.D
	21:47	IV.Ec.R
Mar. 24	0:26	II.Ec.R
	9:09	III.Tr.I
	10:38	I.Oc.D
	12:46	III.Tr.E
	13:04	III.Sh.I
	13:55	I.Ec.R
	16:41	III.Sh.E
Mar. 25	7:47	I.Tr.I
	8:45	I.Sh.I
	10:04	I.Tr.E
	11:03	I.Sh.E
	14:39	II.Tr.I
	16:39	II.Sh.I
	17:32	II.Tr.E
	19:32	II.Sh.E
Mar. 26	5:05	I.Oc.D
	8:24	I.Ec.R
Mar. 27	2:14	I.Tr.I
	3:14	I.Sh.I
	4:31	I.Tr.E
	5:31	I.Sh.E
	8:49	II.Oc.D
	13:44	II.Ec.R
	22:56	III.Oc.D
	23:33	I.Oc.D
Mar. 28	2:36	III.Oc.R
	2:53	I.Ec.R
	3:06	III.Ec.D
	6:47	III.Ec.R
	20:42	I.Tr.I
	21:43	I.Sh.I
	22:58	I.Tr.E
Mar. 29	0:00	I.Sh.E
	3:52	II.Tr.I
	5:58	II.Sh.I
	6:45	II.Tr.E
	8:51	II.Sh.E
	18:00	I.Oc.D
	21:21	I.Ec.R
Mar. 30	15:09	I.Tr.I
	16:12	I.Sh.I
	17:26	I.Tr.E
	18:29	I.Sh.E
	22:01	II.Oc.D
Mar. 31	3:01	II.Ec.R
	12:27	I.Oc.D
	12:44	III.Tr.I
	15:50	I.Ec.R
	16:21	III.Tr.E
	17:02	III.Sh.I
	17:09	IV.Tr.I
	20:40	III.Sh.E
	21:55	IV.Tr.E

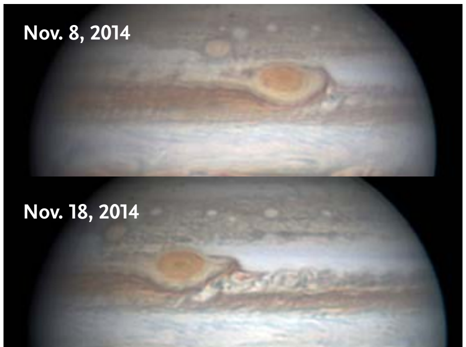
Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 5 hours ahead of Eastern Standard Time; 4 hours ahead of Eastern Daylight Time). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede, or **IV** Callisto. Next is the type of event: **Oc** for an occultation of the satellite behind Jupiter's limb, **Ec** for an eclipse by Jupiter's shadow, **Tr** for a transit across the planet's face, or **Sh** for the satellite casting its own shadow onto Jupiter. An occultation or eclipse begins when the satellite disappears **(D)** and ends when it reappears **(R)**. A transit or shadow passage begins at ingress **(I)** and ends at egress **(E)**. Each event is gradual, taking up to several minutes. Predictions by IMCCE.

Further Action at Jupiter

Jupiter is a month past opposition in March, nice and high by mid-evening and still 44″ to 42″ across its equator as it awaits your telescope.

Any telescope shows Jupiter's four big Galilean moons. Binoculars usually show at least two or three, occasionally all four. Identify them using the diagram on the facing page.

All the March interactions between Jupiter and its satellites and their shadows are tabulated on page 51.



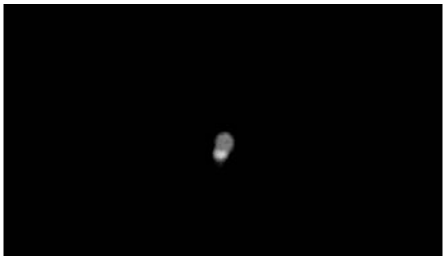
Last November, the Red Spot Hollow showed a dark rim that curled all the way around the Great Red Spot's following end. The rim changed shape in just 10 days.

Mutual events now happening among the satellites themselves are listed on the facing page.

And here are the times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian. The dates, also in UT, are in bold. (Eastern Standard Time is UT minus 5 hours; Eastern Daylight Time is UT minus 4 hours.)

February 1, 6:47, 16:43; **2**, 2:39, 12:34, 22:30; **3**, 8:25, 18:21; **4**, 4:17, 14:12; **5**, 0:08, 10:03, 19:59; **6**, 5:54, 15:50; **7**, 1:46, 11:41, 21:37; **8**, 7:32, 17:28; **9**, 3:24, 13:19, 23:15; **10**, 9:10, 19:06; **11**, 5:02, 14:57; **12**, 0:53, 10:48, 20:44; **13**, 6:39, 16:35; **14**, 2:31, 12:26, 22:22; **15**, 8:17, 18:13; **16**, 4:09, 14:04; **17**, 0:00, 9:55, 19:51; **18**, 5:47, 15:42; **19**, 1:38, 11:33, 21:29; **20**, 7:25, 17:20; **21**, 3:16, 13:12, 23:07; **22**, 9:03, 18:58; **23**, 4:54, 14:50; **24**, 0:45, 10:41, 20:36; **25**, 6:32, 16:28; **26**, 2:23, 12:19, 22:15; **27**, 8:10, 18:06; **28**, 4:01, 13:57, 23:53.

March 1, 9:50, 19:46; **2**, 5:41, 15:37; **3**, 1:32, 11:28, 21:24; **4**, 7:19, 17:15; **5**, 3:11, 13:06, 23:02; **6**, 8:58, 18:53; **7**, 4:49, 14:44; **8**, 0:40, 10:36, 20:31; **9**, 6:27, 16:23; **10**, 2:18, 12:14, 22:10; **11**, 8:05, 18:01; **12**, 3:57, 13:52, 23:48; **13**, 9:44, 19:39; **14**, 5:35, 15:31; **15**, 1:26, 11:22, 21:18; **16**, 7:13, 17:09; **17**, 3:04, 13:00, 22:56; **18**, 8:51, 18:47; **19**, 4:43, 14:39; **20**, 0:34, 10:30, 20:26; **21**, 6:21, 16:17; **22**, 2:13, 12:08, 22:04; **23**, 8:00, 17:55; **24**, 3:51, 13:47, 23:42;



Ganymede (top) partially occulted Io on May 25, 2009, during the last season of Jovian mutual-satellite events half a Jupiter orbit ago. This frame is from a video recording by Mike Salway in Australia using a 12-inch reflector.

MIKE SALWAY

25, 9:38, 19:34; **26**, 5:29, 15:25; **27**, 1:21, 11:17, 21:12; **28**, 7:08, 17:04; **29**, 2:59, 12:55, 22:51; **30**, 8:46, 18:42; **31**, 4:38, 14:34.

These times assume that the spot is centered at about System II longitude 222°; it drifts east or west in ways that are not always predictable. Any feature on Jupiter appears closer to the central meridian than to the limb for 50 minutes before and after transiting. A light blue or green filter slightly boosts the contrast of Jupiter's reddish, orange, and tan markings.

Ganymede shadow – Nov. 23, 2014 · Io shadow – Feb. 9, 2014 · Callisto & Europa shadows – Feb. 6, 2014

CHRISTOPHER GO (SX)

The shadows of Jupiter's moons, like the moons themselves, differ markedly in size. And when seen at such high resolution as this, Callisto's shadow displays a slightly fuzzy penumbra, since Callisto is substantially farther from Jupiter than the others. South is up in all the images.

Mutual Events of Jupiter's Moons

Jupiter's four Galilean satellites will continue to eclipse and occult each other for the next several months. Most of these events involve only slight dimmings of the satellites involved, but others should be plain to see with a very small telescope.

Listed below are the deepest mutual events that will be visible from at least part of North America: those where the shadowed satellite, or the blend of two during a mutual occultation, will fade by at least 0.5 magnitude while Jupiter is visible in a dark sky:

Deep Mutual Events of Jupiter's Moons (for North America)

Date (UT)	Event	Start UT	End UT	Mag. drop
Mar. 1	2*o*1	4:10	4:16	0.6
1	2*e*1	5:02	5:09	0.9
3	3*o*1	4:06	4:11	0.6
3	3*e*1	5:22	5:29	0.6
6	1*e*3	6:35	6:46	1.0
8	2*o*1	6:15	6:21	0.5
8	2*e*1	7:21	7:27	0.8
10	3*o*1	6:31	6:36	0.6
13	1*e*2	3:27	3:31	0.5
13	1*e*3	9:52	10:06	0.8
14	1*e*3	7:50	8:10	0.8
15	2*e*1	9:39	9:45	0.6
16	4*o*2	1:34	1:44	0.8
16	4*e*2	6:46	6:59	0.9
17	3*e*2	2:49	2:57	0.5
20	1*e*2	5:40	5:45	0.6
24	3*e*2	6:04	6:11	0.5
27	1*e*2	7:53	7:58	0.6

Under "Event," satellite 1 is Io, 2 is Europa, 3 is Ganymede, and 4 is Callisto; *o* means occults, and *e* means eclipses.

For instance, from 4:10 to 4:16 March 1st UT (11:10 to 11:16 p.m. February 28th EST), Europa occults Io. You can watch them draw together and seem to merge, and then their combined light will dip by a noticeable 0.6 magnitude before they visibly draw apart again. Judge the brightness carefully against the brightnesses of Jupiter's other moons.

Note the pairs of events that happen only about an hour apart on March 1st, 3rd, and 8th UT.

For the complete list of all these events visible around the world, sortable by location, see **skypub.com/jovianmutualevents**. There you'll also find links to the global campaign to time them photometrically, to refine our knowledge of the slight but important ongoing changes in the Jovian satellites' orbits.

Lunar Occultation

Early on the evening of February 28th, the dark limb of the waxing gibbous Moon will occult 3.6-magnitude Lambda Geminorum for most of North America east of the Mississippi and north of the Mason-Dixon Line. Some times: central Massachusetts, 8:00 p.m. EST; Washington DC, 7:56 p.m. EST; Chicago, 6:31 p.m. CST (in twilight); Kansas City, 6:21 p.m. CST (in twilight). For a map and detailed timetables, check **lunar-occultations.com/iota/bstar/bstar.htm** as the date draws near.

Asteroid Occultations

Among the many predicted occultations of telescopic stars by faint asteroids:

- **On the morning of March 5th,** an 8.7-magnitude star northeast of Antares will be occulted by faint 72 Feronia for up to 4 seconds along a path from southern California across northern Arizona.
- **On the morning of March 7th,** an 8.4-magnitude star in the vicinity of M83 in Hydra, far south of Spica, will be occulted by faint 506 Marion for up to 10 seconds as seen from southern California, likely including Greater Los Angeles. The star will be low in the southwest.

For time predictions, track maps, finder charts for the stars, and predictions for more asteroid occultations worldwide, see **asteroidoccultation.com/IndexAll.htm**. ✦

Jupiter's Moons

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

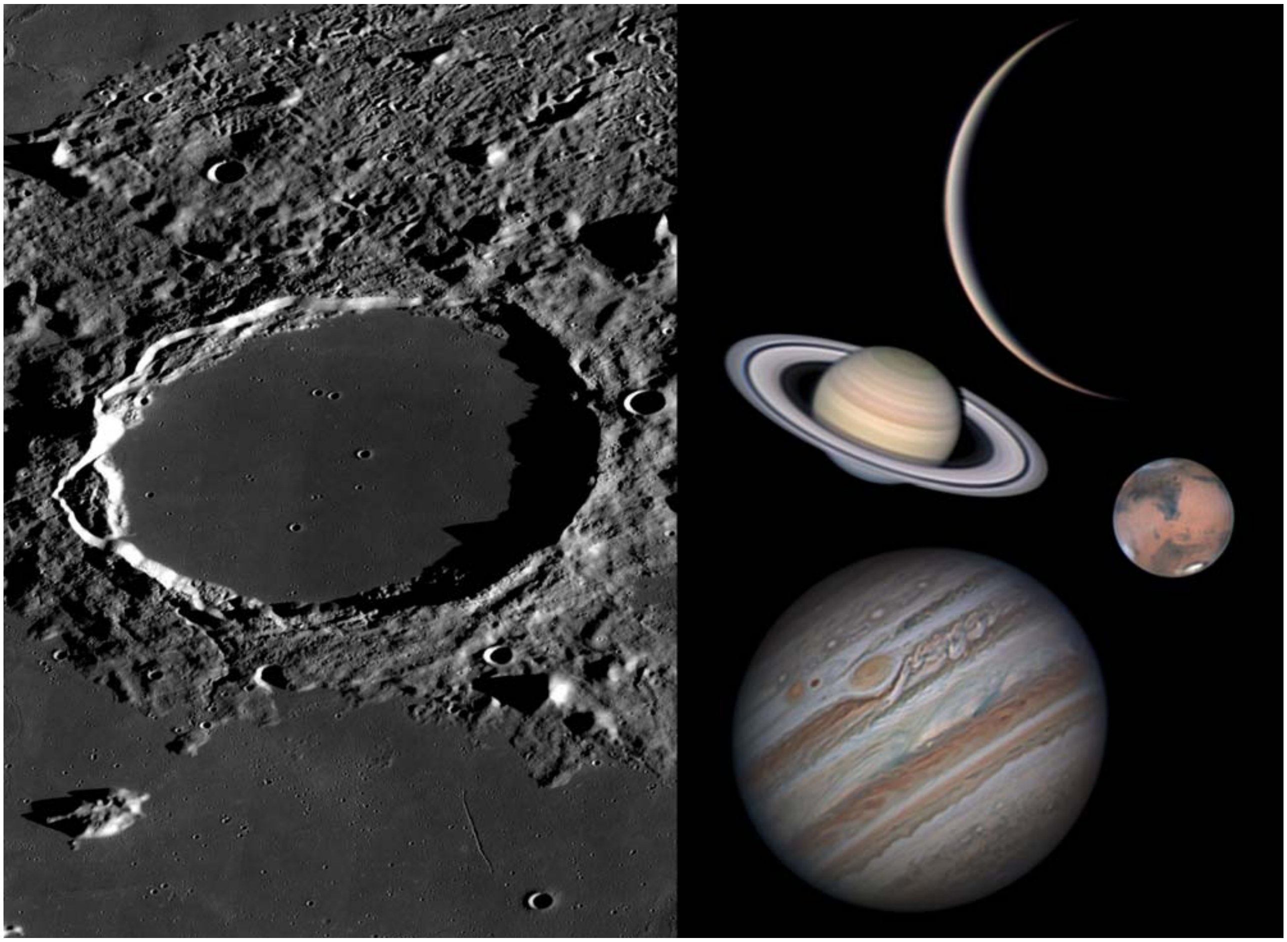
Powering Up

Choose the right magnification for your planetary observing experience.

For planetary observers, selecting the optimal magnification requires striking a delicate balance between the size and sharpness of the image while preserving sufficient image brightness.

A minimum magnification is required for the human eye to fully exploit the resolving power of any telescope. Most sources cite a rather modest value of 13× per inch of aperture that was derived from studies that used test charts of very high contrast — black markings on a white background. Of course, the contrast of most planetary markings is far more subdued. When low-contrast test charts that closely mimic planetary subjects are employed, this value increases by a factor of two or even three, corresponding to at least 26× to as much as 39× per inch of aperture. If we use the latter figure, to fully exploit the resolving power of a 4-inch telescope requires a magnification of 156×, while a 16-inch telescope requires no less than a whopping 624×.

Provided that a telescope has sufficient optical quality, the single most important factor in determining the clarity of the planetary images that it will deliver is the tranquility of the Earth's atmosphere. "The atmosphere," lamented the French astronomer André Couder, "is the worst part of the instrument." "Seeing" is caused by tur-


PLATO: NASA / GSFC / ARIZONA STATE UNIVERSITY, PLANETS: SEAN WALKER

Shown here to approximate scale, the planets never appear as large as the lunar crater Plato. Seeing detail on the planets requires high magnifications, but how high is too high?

***Thomas Dobbins** began observing the planets when Lyndon Johnson was President of the United States.*

bulent air cells at altitudes ranging from several hundred feet to ten miles that have different temperatures and hence different indices of refraction. At most observing sites these atmospheric cells usually range in size from four to eight inches in diameter, although research by atmospheric physicists has revealed that they can vary tremendously in size. Each cell acts as a lens, changing the focal position of the image by bending incoming rays of light differently.

If the aperture of a telescope is large enough to receive light that has passed through many air cells, a blurred, "washed-out," or "boiling" image will result. But when the aperture of a telescope is approximately the same diameter as the air cells, the image will be well defined, although sharpest focus may change as individual cells drift across the light path.

The larger the aperture of the telescope, the smaller the probability that the air mass over it will be optically homogeneous at any given moment. When it comes to resolving planetary details, telescopes of modest aperture (from 8 to 10 inches in diameter) are disproportionately efficient compared to large instruments, resolving to their theoretical limits on a far greater number of nights. In 1885, the American astronomer Asaph Hall remarked: "There is too much skepticism on the part of those who work with large instruments in regard to what can be seen with small ones."

The remarkably high efficiency of modest-aperture telescopes is accurately reflected in a five-decade-old formula devised by the German planetary observer Günter Roth. According to Roth, the maximum practical magnification for planetary observing corresponds to 140 multiplied by the square root of the aperture in inches, as tabulated below.

Aperture (inches)	Maximum useful magnification	Power per inch
4	280×	70×
6	343×	57×
10	443×	44×
16	560×	35×
24	686×	29×
36	840×	23×

The experience of Edward Emerson Barnard, the preeminent American planetary observer of the 19th century, lends credence to Roth's formula. According to Barnard, the best planetary images through the 36-inch Lick refractor were obtained with magnifications of 360× to 540× (10× to 15× per inch of aperture), with no improvement beyond 1000× (28× per inch of aperture) even on exceptionally steady nights.

Barnard's contemporary, the Greco-French astronomer Eugène Antoniadi, also preferred to use comparatively low magnifications with the 33-inch Meudon refractor at the Paris Observatory. His best views of Mars and Jupiter were obtained with magnifications of only 320× to 540× (10× to 16× per inch of aperture).

If large telescopes are so handicapped by atmospheric turbulence that they usually fail to resolve details beyond the capabilities of a 12- to 16-inch aperture, why do they often deliver more revealing views of the planets than smaller instruments? The answer lies in *image brightness*, which is essential for perceiving subtle differences in both tone and hue.

The luminances (apparent brightness per unit area) of the planets compared to the full Moon are shown in the table below:

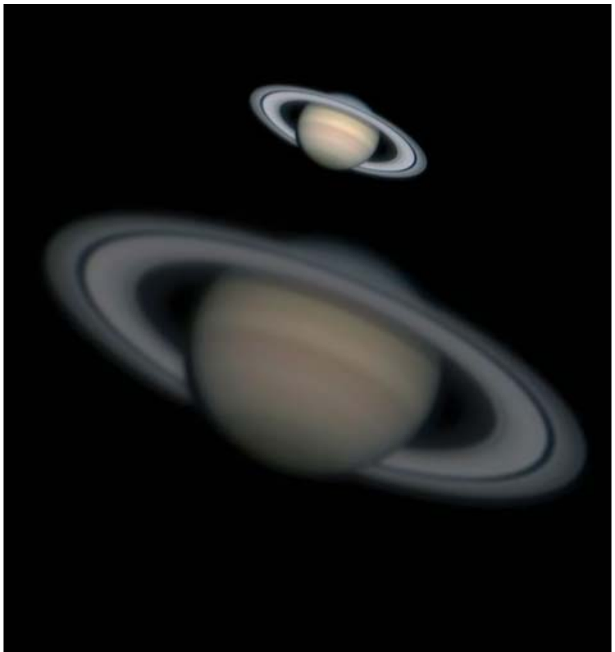
Full Moon	**1.0**
Mercury	**5.8**
Venus	**9.6**
Mars	**0.55**
Jupiter	**0.15**
Saturn	**0.045**
Uranus	**0.013**
Neptune	**0.005**

With large apertures, the excessive surface brightness of the Moon, Venus, and Mars results in troublesome glare that must be reduced using neutral density or color filters. However, the apparent surface brightness of Jupiter is only one-third that of Mars, and the apparent surface brightness of Saturn is in turn only one-third that of Jupiter. The features of the gas giants consist of a palette of delicate pastel hues of rather modest contrast. Jupiter's belts and zones typically differ in apparent brightness by 10% to 20% percent, while the contrast of Saturn's belts and zones, muted by the presence of high-altitude atmospheric hazes, usually amount to only 5% to 15%. If the image is large but dim, it becomes difficult to perceive subtle differences of contrast and color.

The leading British Jupiter observer of the late 19th century, William Frederick Denning, was equipped with an excellent 12.6-inch Newtonian reflector. He found that magnifications of 205× and 225× gave superb definition but images that were too small. The best power for Jupiter (and planetary observing in general) proved to be 315×, while 404× and 450× offered no advantage except on the very best nights. Denning's results are representative of the general consensus that has emerged among experienced planetary observers.

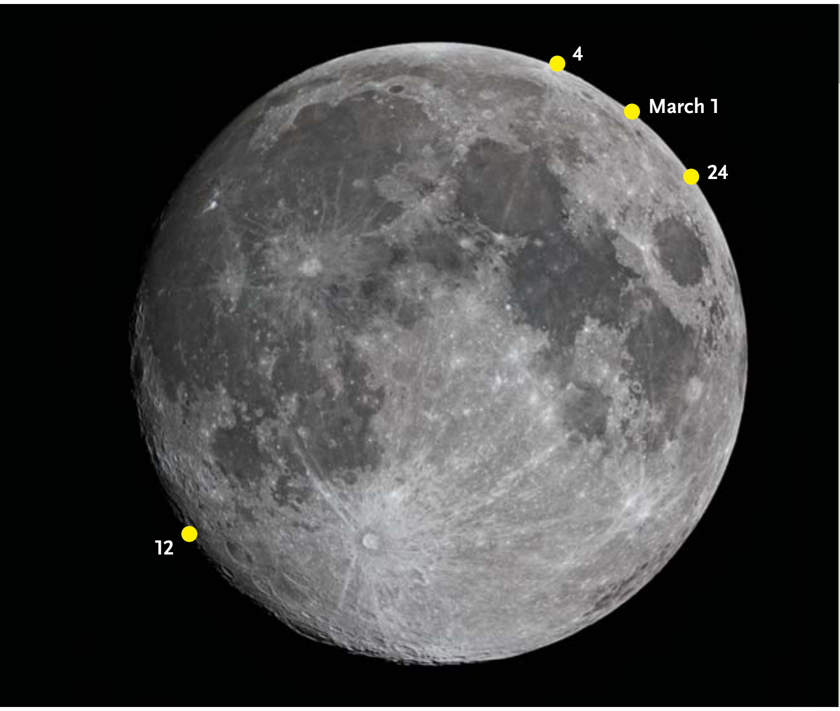
The old Roman axiom *De gustibus non es disputandum* ("In matters of taste there can be no disputes") certainly holds true when it comes to magnification. Individual differences in visual acuity and even temperament play a role. Some observers prefer to use comparatively high magnifications even under rather adverse seeing conditions, waiting patiently for any fleeting moments when the seeing momentarily improves.

The selenographer Johann Heinrich von Mädler was an extreme example of the "wait it out" school. He routinely used 400× with his 4-inch Fraunhofer refractor when observing the Moon to produce (in collaboration with Wilhelm Beer) *Mappa Selenographica* and the first decent map of Mars. On the other end of the spectrum was the keen-eyed Philipp Fauth, one of the leading German lunar and planetary observers of the early 20th century. Fauth usually employed magnifications of only 25× per inch with his 6-, 7-, and 15-inch refractors, reserving the highest magnifications of only 38× per inch only for the finest nights. "Sharpness is more important than image scale," he wrote. Every observer has his or her own personal equation, and it may change over the years. ✦



Doubling magnification reduces the apparent surface brightness of an extended object like a planet by a factor of four. Too large an image scale also dilutes colors and washes out low-contrast features. This pair of Saturn images above simulates the problem and really drives home the notion of "empty magnification."

SEAN WALKER



S&T: DENNIS DI CICCO

The Moon • March 2015

Phases

FULL MOON
March 5, 18:05 UT

LAST QUARTER
March 13, 17:48 UT

NEW MOON
March 20, 9:36 UT

FIRST QUARTER
March 27, 7:43 UT

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

Distances

Apogee	March 5, 8h UT
252,516 miles	diam. 29′ 24″
Perigee	March 19, 20h UT
222,192 miles	diam. 33′ 25″

Librations

Boss (crater)	March 1
Cusanus (crater)	March 4
Drude (crater)	March 12
Gauss (crater)	March 24

Happy Anniversary!

Celebrate a century of Melotte's star clusters.

One hundred years ago this month, *A Catalogue of Star Clusters shown on Franklin-Adams Chart Plates*, by Philibert Jacques Melotte, was received and read by the Royal Astronomical Society. Most of the clusters were previously known, but this comprehensive catalog was an effort to shed light on the distribution of both open and globular clusters. These were key factors in determining the structure of our galaxy and our position within it.

Let's take a look at some of the open clusters in Melotte's catalog that are well-placed for viewing at this time of the year.

We'll begin with **NGC 2324** (Melotte 59), located 2.5° northwest of Delta (δ) Monocerotis. Through my 105-mm refractor at 68×, NGC 2324 emerges as a pretty web of mist bedewed with a smattering of very faint stars. At 87× its apparent diameter is 7′. I count 17 stars: one 10th magnitude and the rest 12th and 13th magnitude. Another 10th-magnitude star nuzzles the cluster's north-eastern rim, and beyond it lies an array of 9th- and 10th-magnitude stars fashioned into an elegant V with curved sides. In my 10-inch reflector, NGC 2324 becomes a quite beautiful group, rich in very faint stars.

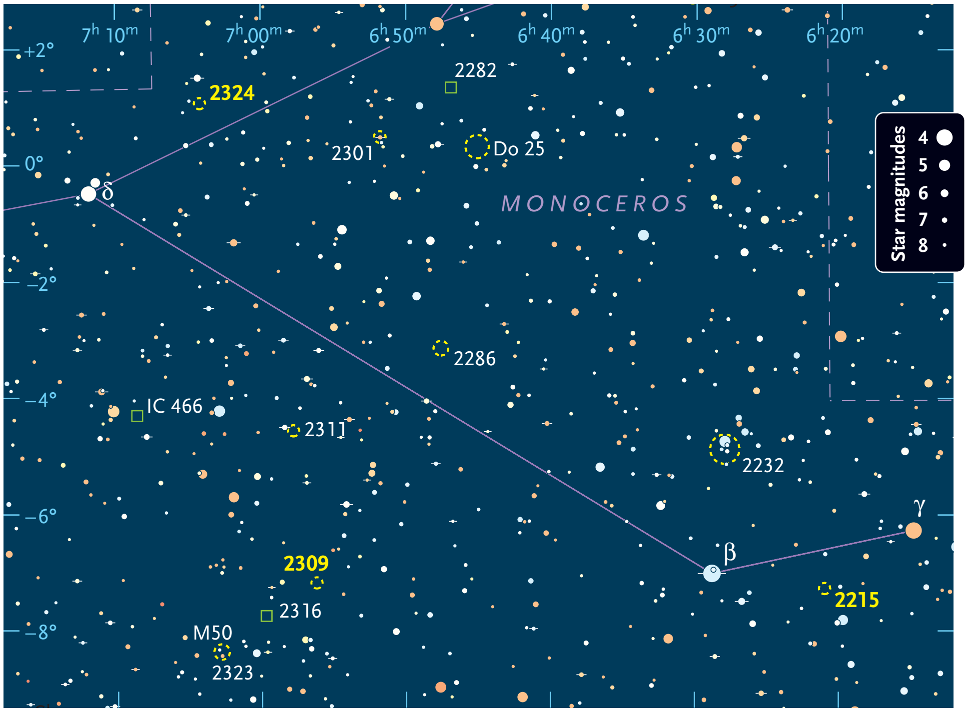
Dropping southward to **NGC 2309** (Melotte 56), my 105-mm scope at 17× reveals a small, bright, fuzzy spot with a 9th-magnitude star near its north-northeastern edge. It shares the field of view with the splashier cluster Messier 50, perched 2° southeast. At 47× NGC 2309 seems to be nested amid ribbons of darkness that enhance the cluster's prominence in the sky. At 87× I count 14 stars in a 4½′ group that still holds a trace of haze in its heart. My 10-inch scope at 213× unveils a crowd of faint to extremely faint stars over a milky backdrop of unresolved suns.

NGC 2309 and NGC 2324 reside in the near and far sides of our galaxy's Perseus Arm, the next spiral arm outward from the arm segment where our Sun dwells. The rest of the clusters in this tour share the Orion Spur with our Sun and are strung along it at various distances from us. The table on p. 58 includes distances obtained from the open-cluster database WEBDA (**webda.physics.muni.cz**).

The Orion Spur cluster **NGC 2215** (Melotte 45) lies south of an imaginary line connecting Beta (β) and Gamma (γ) Monocerotis. My 105-mm refractor at 17× shows a little patch of mist with a grainy texture. At 87×

An edge-on galaxy floats about 4° to the south-southwest of the dense tangle of stars forming NGC 2509.

POSS-II / CALTECH / PALOMAR OBSERVATORY



about 25 faint stars are sprinkled over a touch of slightly mottled haze. My 10-inch reflector at 70× reveals a pretty group of 38 stars, 10th to 13th magnitude, filling a squarish shape with a 10′ diagonal. The stars are fairly evenly scattered, with the brightest congregating mostly in the central region.

NGC 2509 (Melotte 81) in Puppis is the nearest cluster we'll visit, only 3,000 light-years away from us. For an open cluster it's quite ancient, but just how ancient is still in question. Recent estimates of its age run from 1 billion to 8 billion years. Look for the cluster 1.9° west and a bit north of 4th-magnitude 16 Puppis.

NGC 2509 is a bright foggy patch flecked with stars through my 105-mm refractor at 17×. A 5th-magnitude star sits 41′ to the cluster's north-northwest, and a 9th-magnitude star guards its southeastern border. At 47× NGC 2509 is a dense knot of faint stars and bright mist, with a halo of dim stars that extends mostly southwest, through east, to northeast of the knot. I estimate dimensions of 8′ × 5′. About 25 stars are visible at 87×, some of the brightest making a rectangular box with the bright region packed into its northwestern side. The cluster looks almost completely resolved by my 10-inch scope at 187×, showing 40 faint to extremely faint stars, most crowded into the group's northern half.

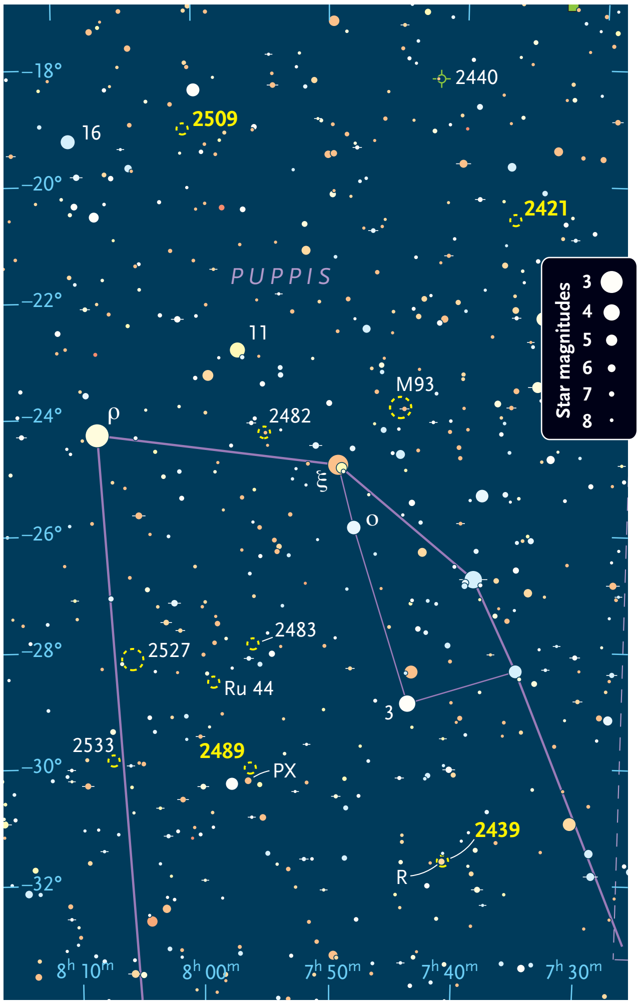
Images of NGC 2509 show a faint edge-on galaxy 3.9′ south-southwest of the cluster's dense knot of stars. Its visual magnitude is probably somewhere in the vicinity of 15.5. Can anyone spot it?

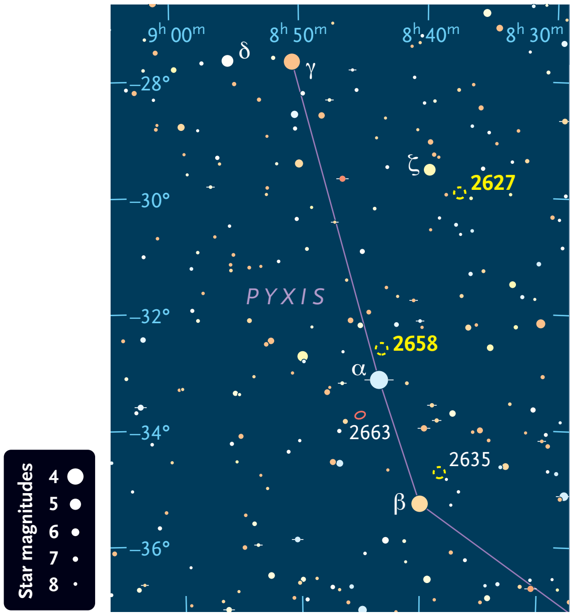
Now picture an imaginary line from Rho (ρ) Puppis to 11 Puppis and extend it twice that distance to find our next cluster, **NGC 2421** (Melotte 67). My 105-mm refractor at 17× shows a fairly bright, round glow speckled with diamond-dust stars. At 47× the cluster resembles a star-spangled bowtie, tipped a bit away from us so that the near end is east-northeast. I count 25 stars in a group that spans 10′. A pair of 9th-magnitude stars sits 11′ northwest of the cluster and points toward it. About 35 stars emerge at a magnification of 87×. NGC 2421 has a rather triangular appearance in my 10-inch reflector at 88×, largely due to prominent triangles of stars at the cluster's north, south-southeast, and south-southwest edges.

NGC 2489 (Melotte 79) hovers 13′ north of the 6th-magnitude red giant PX Puppis, which has low-amplitude variability of about 0.4 magnitude. NGC 2489 is a bright, granular haze through my 105-mm scope at 17×. At 87× it displays about 15 stars, surrounded by a gap and sitting in a bucket of stars open north-northwest. The bucket is about 9′ wide and the starry ball being carried inside is 5′ across. My 10-inch scope at 115× pries 35 faint to very faint stars out of the haze, forming a cluster that spans 8′.

Sliding 3.7° to the west-southwest from NGC 2489 takes

POSS-II / CALTECH / PALOMAR OBSERVATORY





Melotte's Open Clusters

Object	Con	Mag(v)	Size/Sep.	Distance (l-y)	RA	Dec.
NGC 2324	Mon	8.4	8′	12,400	7^h 04.1^m	+1° 03′
NGC 2309	Mon	10.5	5′	8,200	6^h 56.1^m	–7° 11′
NGC 2215	Mon	8.4	11′	4,200	6^h 20.8^m	–7° 17′
NGC 2509	Pup	9.3	12′	3,000	8^h 00.8^m	–19° 03′
NGC 2421	Pup	8.3	10′	7,100	7^h 36.2^m	–20° 37′
NGC 2489	Pup	7.9	8′	12,900	7^h 56.3^m	–30° 04′
NGC 2439	Pup	6.9	9′	12,600	7^h 40.8^m	–31° 42′
NGC 2627	Pyx	8.4	11′	6,600	8^h 37.3^m	–29° 57′
NGC 2658	Pyx	9.2	10′	6,600	8^h 43.5^m	–32° 39′

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.

us to **NGC 2439** (Melotte 74). It enfolds the yellow supergiant R Puppis, another low-amplitude variable star. In my 105-mm refractor at 17×, R Puppis and three dimmer stars make a little kite in the northeastern part of a hazy glow that they share with four faint stars. At 47× two of the kite stars become double, and 14 additional stars appear. At 87× NGC 2439 is a pretty scattering of sparkly star motes, containing 32 members within a diameter of 8′.

NGC 2439 and NGC 2489 are the youngest star clusters in our tour, each with an age of only 18 million years. They have nearly the same galactic longitude, but NGC 2439 is a little closer to us and farther below the galactic plane than NGC 2489. This puts them roughly 900 light-years apart.

Just 350 light-years apart, NGC 2627 (Melotte 87) and NGC 2658 (Melotte 90) in Pyxis are the last stops on our anniversary tour.

NGC 2627 rests 40′ southwest of Zeta (ζ) Pyxidis. My 105-mm scope at 28× shows an east-west haze freckled with faint stars. A 9th-magnitude sun closely watches its east-northeastern edge. New York amateur Joe Bergeron brought a detached fuzz spot 6′ south of NGC 2627's center to my attention. This tiny island of mist is within the cluster's apparent boundaries as given in the *Milky Way Global Survey of Star Clusters* (Nina V. Kharchenko and colleagues, 2013), and one of its stars is considered a likely member. At 87× I see a hazy glow adorned with 30 stars covering 11′ × 5½′, while the detached spot gives up only six stars in a triangular shape. At this same magnification, **NGC 2658**, which floats 32′ north of Alpha (α) Pyxidis, is an attractive sight boasting a liberal dose of very faint star specks over haze. Through my 10-inch scope at 187×, the center of NGC 2658 is dominated by a broken ring of stars that outshines its surroundings and measures 1½′ × 1¼′. NGC 2658 sits in an open box outlined by brighter field stars, and the cluster's southwestern reaches ooze through the box's bottom.

I'd like to thank astronomy author and astrogeologist Brent A. Archinal for providing the inspiration for this centennial celebration. Visit Melotte's catalog online courtesy of **http://adsabs.harvard.edu/abs/1915MmRAS..60..175M**. ✦

shown on Franklin-Adams Chart Plates. 181

A Catalogue of Star Clusters shown on Franklin-Adams Chart Plates—continued.

No.	No. in N.G.C.	R.A. 1900.	Dec. 1900.	L.	λ.	Diam.	Class.	Description.
67	2421	7 31·9	−20 23	204	+ 0·9	8	II.	Small, loose cluster in a dense region.
68	2422	7 32·0	−14 16	199	+ 3·9	25	II.	A loose cluster, includes some bright stars.
69	2420	7 32·5	+21 48	165	+20·1	7	II.	Small, well-defined cluster. Condenses gradually towards centre. Almost globular in appearance.
70	2423	7 32·5	−13 38	199	+ 4·5	20	III.	A loose cluster, not very well defined.
71		7 32·9	−11 50	197	+ 5·8	8	II.	A small, well-defined cluster of faint stars. Condensed towards centre.
72		7 33·7	−10 27	196	+ 6·7	5	III.	A small, loose clustering of faint stars. Not well defined.
73	2432	7 36·5	−18 51	204	+ 2·9	4	III.	Small clustering in a rich region.
74	2439	7 37·0	−31 25	214	− 3·6	9	II.	A distinct cluster; includes some bright stars.
79	2489	7 52·2	−29 48	214	+ 0·2	7	II.	Well-defined cluster in a dense region.
80	2506	7 55·2	−10 21	198	+10·8	10	II.	Cluster of faint stars, condensing well towards centre. Almost Class I.
81	2509	7 56·3	−18 48	205	+ 6·6	4	II.	A small clustering in a rich region. Not well defined.
82	2516	7 56·7	−60 36	241	−15·0	60	II.	Fine open cluster of bright stars, extending over a field quite 1° square.
83	2539	8 6·0	−12 32	201	+12·2	21	II.	An open cluster.
84	2547	8 7·7	−48 58	232	− 7·6	15	III.	An irregular cluster of stars; many bright.
85	2548	8 8·8	− 5 30	195	+16·2	30	II.	A very open cluster of irregular outline.
86	2567	8 14·6	−30 20	217	+ 3·8	10	II.	Distinct cluster in a rich region. Resembles N.G.C. 2489 and 2627.
87	2627	8 33·1	−29 36	219	+ 7·7	8	II.	Well-defined cluster in a dense region.
88	2632	8 34·3	+20 20	172	+33·2		II.	M. 44. Præsepe. Extends over a field quite 2° square.
89	2635	8 34·5	−34 25	224	+ 4·8	3	III.	A small cluster, not very well defined.
90	2658	8 39·4	−32 18	222	+ 7·3	9	II.	A cluster in a dense region.
91	2659	8 39·2	−44 36	232	− 0·8	10	III.	A loose cluster in a rich region.

Jerry Lodriguss

iOptron's SkyGuider

Here's a sturdy camera tracker for nightscape photographers on the go.

iOptron SkyGuider with Tripod

US price: $578.
Available from www.ioptron.com and through dealers worldwide.

WHAT WE LIKE:

Alignment scope accuracy

Solidity for its size

WHAT WE DON'T LIKE:

Tripod height

Polar scope illuminator plug

The extremely portable and lightweight SkyGuider tracking mount is targeted at the "nightscape" astrophotographer who travels to remote locations. Note the ball head is not included in the price of the mount. All photos are courtesy of the author.

ALL IMAGES BY JERRY LODRIGUSS

Long have I dreamed the same dreams as all serious astrophotographers – clear skies, steady seeing, and a simpler life with fewer wires and cables. Sometimes I have up to a dozen cables on my imaging setup, including those for power, dew heaters, an autoguider, cameras, and a USB connection to a laptop computer. Fantasies of a life free of this bird's nest of cables often dance in my head.

iOptron's new SkyGuider mount goes a long way towards fulfilling those dreams of simplicity while at the same time giving the flexibility to go a bit more advanced if you so desire. The mount can be used with a camera and lens with just a single power cable, or with an autoguider for longer focal lengths and more complex setups.

I acquired a SkyGuider on loan from iOptron, including the field tripod and the company's custom ball head. This mount fits into iOptron's product lineup between the SkyTracker (*S&T*: May 2013, p. 64) and the SmartEQ Pro. The tracking performance should be similar to the ZEQ25 mount (*S&T*: March 2014, p. 60), which shares the same right-ascension drive and motor.

This bare-bones equatorial mount is primarily intended for wide-field astrophotography. It includes a right-ascension drive but lacks a traditional declination assembly. Instead, an optional ball head or other camera mounting is used to hold and aim your camera and lens. Its single axis precludes Go To pointing, slewing, and computer control. It does, however, include an autoguider port, which allows drive corrections in right ascension.

The SkyGuider is perfect for imagers with heavier cameras and lenses than the company's smaller SkyTracker can accommodate. It's rated to handle a payload of 11 lbs, in addition to up to 7.7 lb of counterweights. It should be noted that some configurations may require the purchase of an additional counterweight.

Weighing in at just 5.5 lbs, the mount head can be purchased separately for $479, or with the field tripod as reviewed here. Padded carrying cases are included for both the mount and tripod. The entire package is lightweight yet solid, and it's easy to pick up and move. Both easily meet airline carry-on limits and should be a great platform for small scopes or telephoto lenses used to shoot solar eclipses, with a few additional accessories.

iOptron's Field Tripod

The optional field tripod included in the review package is very solid, utilizing dual-section, 1½-inch stainless-steel legs with a durable plastic spreader. Its one drawback is its limited height. When fully extended, the field tripod places the polar alignment scope eyepiece just over 30 inches above ground. This means you have to sit on the ground to look through it.

The SkyGuider includes a metal screw-on cap to protect the polar finder scope. The knob on the side engages the worm into the right-ascension gear. You adjust the mesh of the worm with the knob on the top of the black gear box.

The mount includes a built-in bubble level to aid in leveling the device before fine-tuning polar alignment, and an incremental altitude scale to help you roughly adjust for your local latitude.

If you intend to use the SkyGuider on a standard photographic tripod, note that the base of the mount head is not flat and will require a custom ring plate adapter. The manufacturer informs us that future purchase of the SkyGuider tracking head will include this adapter.

Setup

Assembling and aligning the SkyGuider is a brief process, with a few caveats. Attaching the head to the field tripod is straightforward. But before mounting your camera, the SkyGuider requires users to release the right-ascension gear switch to disengage the worm to aid

in balancing your camera. Note that once everything is locked down, the mount does not have a clutch assembly that will slip if it is manhandled. iOptron warns that you will degrade or damage the gear's performance if you try to move it with the gear engaged.

Once you've attached your camera, the mount can then be polar aligned. The SkyGuider comes with the company's built-in polar alignment scope included in all of iOptron's high-end equatorial mounts. A red LED bulb screws into the polar scope, and its power cable conveniently plugs into the control box on the mount so no additional batteries are required, but the plug did tend to pop out frequently. There is no brightness adjustment for the LED.

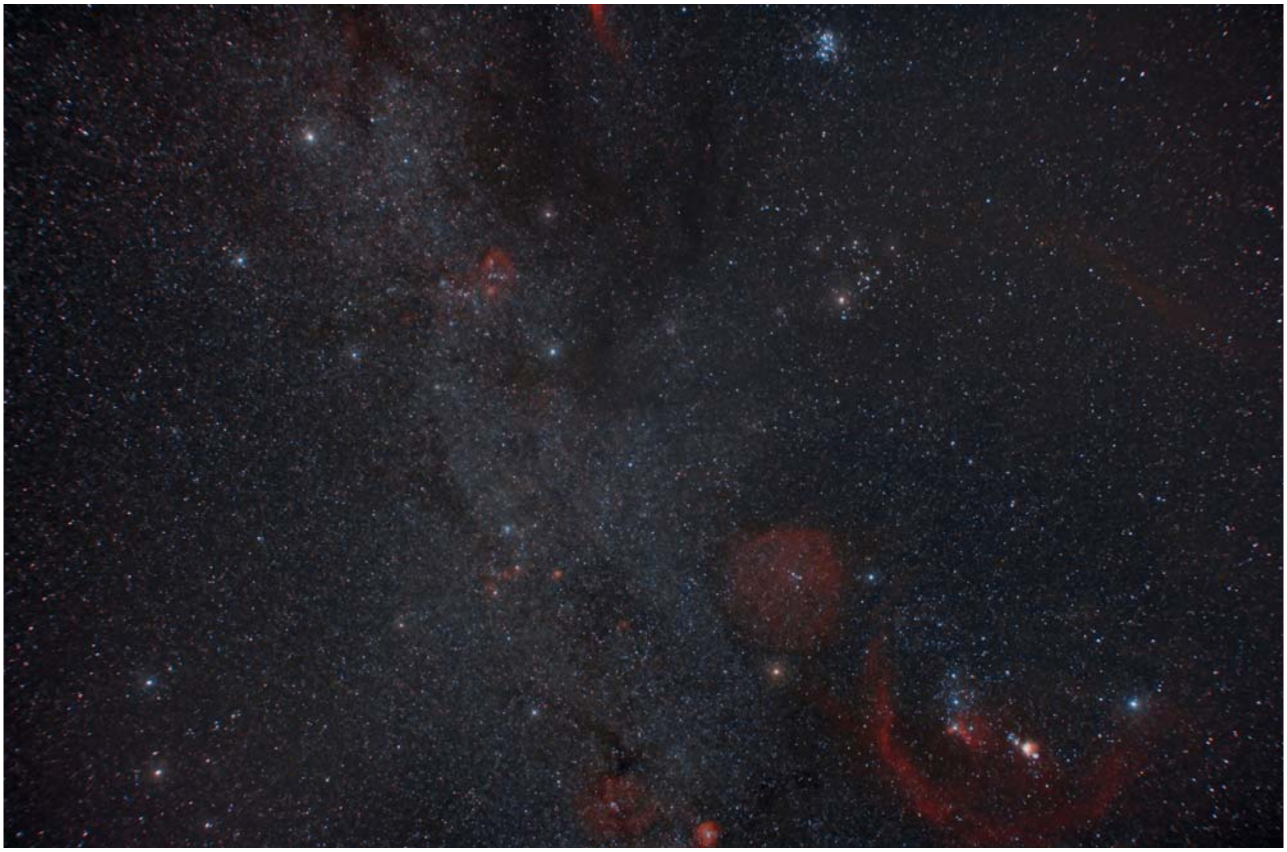
Fine-tuning the mount's polar alignment is done using the azimuth adjustment knobs and a turnbuckle-style latitude adjustment knob. The mount ships with two different lengths of latitude adjustment knobs, allowing you to use the SkyGuider anywhere between 0° and 60° in either the Northern or Southern Hemisphere. When you've aligned the mount, this LED can then be unplugged and removed so the metal protective polar scope cover can be replaced. Be careful not to lose the LED illuminator as it's very small.

No complex calculations or mental gymnastics are needed to align the reticle in the polar scope — you only need to orient it with the 12-hour mark at the top. Instead, iOptron provides an innovative *iOptron Polar Scope* app for Apple mobile devices that uses their built-in GPS and time to display exactly where Polaris should be placed on the reticle. This app is available in the iTunes App Store for $1.99. For Android devices, *Polar Finder* by Tech-Head is available in the Google Play store for $1.18, and it includes the iOptron reticle pattern (among others). If you use the *Polar Finder* app, be sure to select "telescopic" in the setup menu so its view is inverted to match the view in the iOptron polar scope.

Compared to the smaller SkyTracker, the SkyGuider includes a removable counterweight assembly that allows you to balance heavier loads or even replace the counterweight shaft entirely with an additional ball head so you can shoot with two cameras simultaneously. This allows you to double your imaging productivity in a single night.

***Top*: After you've engaged the worm gear and adjusted its tension, you can swing the mount freely by loosening the two black knobs on the right-ascension axis. You perform altitude adjustments using the black turnbuckle knob attached to threaded brass posts. A shorter turnbuckle is included for users at lower latitudes.**

***Bottom*: Although designed to be a wide-field photography tracking platform, the SkyGuider includes an ST-4-compatible autoguider port, as well as multiple drive rates for tracking the Moon (L) and Sun (S). It also incorporates 1× sidereal for normal tracking, as well as a 0.5× sidereal drive rate, which is useful for nightscape photographers who want to split the trailing of the stars and blurring of foreground objects in a single photo.**



This wide-field image of Auriga, Taurus, Gemini, and Orion was taken with a modified Canon Rebel XS and 16-mm lens and combines nine exposures of 8 minutes each. It was shot simultaneously with another camera using a second ball head in place of the counterweight shaft.

The optional iOptron Ball Head included in the review package weighs in at 14 ounces and is quite solid, and it's a good value at $58. This ball head is good for wide-angle to moderate telephoto lenses, but large, heavy zoom lenses and telescopes are a bit too much for it. Note that if you want to use your own ball head, the SkyGuider requires ⅜-16 threads instead of the more common ¼-20 threads. It incorporates a quick-release dovetail plate, which allows you to effortlessly swap out your camera and lens in the dark. Additional dovetail plates for the ball head are available for $15.

A better solution for a big lens or small scope is to use a flat panorama base like the third-party Feisol PB-70 (not sold by iOptron). This places the payload closer to the right-ascension axis, reducing the amount of counterweights needed to balance the mount, and it also provides a much more solid platform for a heavy imaging rig than the ball head.

In the Field

Under the stars last autumn, unguided images with a 16-mm lens produced pinpoint stars across the field of my modified Canon EOS T3i DSLR with 8-minute exposures. Increasing the focal length using a 50-mm lens, 9 out of 10 images of the same duration were perfectly tracked. Moving up to 85 mm, 6 out of 10 frames were well tracked. At 200 mm, exposures longer than 2 minutes all suffered from guiding errors, but 2-minute exposures produced 5 usable frames out of 10.

Trailed stars in declination usually mean polar misalignment — something that shouldn't be a problem with the accuracy of the mount's polar scope. Trailed stars in right ascension at longer focal lengths during long exposures are due to periodic error in the mount's right ascension gears (an issue inherent in all mounts using gears). This can be reduced greatly by using an autoguider and small guidescope or off-axis guider.

SkyGuider's aluminum alloy right-ascension gear has 144 teeth and is 88 mm in diameter, with a repeating period of about 10 minutes. I measured the periodic error of the SkyGuider to be about 30 to 35 arcseconds. This is more than adequate for wide-angle lenses and even some telephoto shots, but as my tests showed, if you intend to photograph with lenses of about 200 mm or more, you will need to start guiding, especially for exposures longer than a couple of minutes.

With the aid of autoguiding, I was able to achieve guiding accuracy of better than 1.5 arcseconds with a small refractor of 420-mm focal length, after carefully balancing the payload and adjusting the gear mesh. I guided through an off-axis guider and Lodestar autoguider using *PHD2* software (**http://stark-labs.com/phdguiding.html**), achieving a 50% success rate with 6-minute exposures. This kind of accuracy is quite good for such a small mount, though it still required replacing the ball head with the rudimentary declination assembly noted earlier.

Final Thoughts

The one thing that would make this a more attractive package would be if iOptron offered a declination assembly option in addition to its ball head. While a ball head is adequate for a camera with wide-angle lenses, it isn't quite up to the task of rigidly supporting longer telephoto lenses or small telescopes closer to the mount's rated weight capacity. A simple declination assembly option like a pan head base would make the mount much more usable for equipment up to the mount's recommended payload limit, particularly since it also includes both lunar and solar tracking speeds. This would make the SkyGuider a highly desirable eclipse photography platform.

Overall, the SkyGuider was easy to set up and use. It's an extremely solid platform for most camera and lens combinations and can even hold a small scope on a pan head in a pinch. You'll be able to take wonderful unguided images with this mount using wide-angle to moderate telephoto lenses. ✦

Jerry Lodriguss is a photographer based in suburban Philadelphia. See more of his images at **www.astropix.com**.

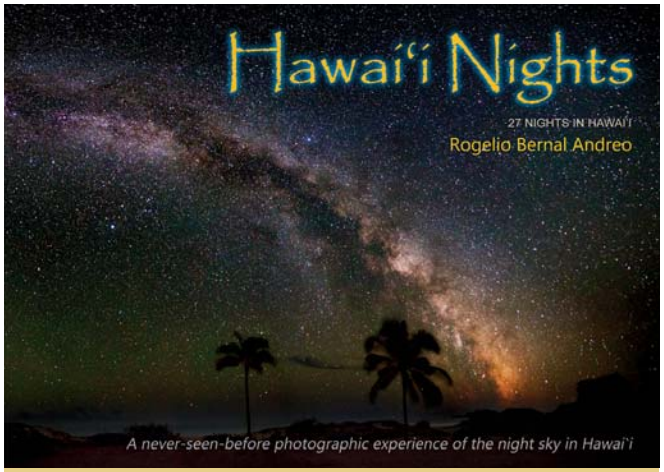
While the SkyGuider can support longer telephoto lenses, its roughly 30-arcsecond periodic error reduces the number of successful unguided exposures. This image of the North America and Pelican nebulae consists of 23 exposures of 3 minutes each shot through a Nikon 180-mm lens. Although twice as many images were recorded, half displayed guiding errors.

◄ SPHINX TWO Vixen's New Sphinx SX2 Equatorial Mount ($1,599) is the latest entry in its line of award-winning telescope mounts. This German Equatorial Go To mount features 180-tooth aluminum alloy gears and brass worms driven by precision stepper motors in both right-ascension and declination axes. The Sphinx SX2 is usable between 0° and 70° latitude and includes a retractable stainless steel counterweight shaft. Both RA and dec motors are housed within the declination axis, functioning as a built-in counterweight. The mount includes manual slow-motion knobs on both axes, and a 4.2-lb counterweight. The SX2 also comes with Vixen's new Star Book One Go To hand controller, allowing you to slew at up to 999× sidereal rate to thousands of targets. The mount accepts the standard ST-4-style autoguider input for astrophotography and also includes a cigarette lighter DC power adapter. See the manufacturer's website for additional details and accessories.

Vixen Optics
1050 Calle Amanecer Ste C, San Clemente, CA 92673
949-429-6363; www.vixenoptics.com

▼ DIGITAL CATALOG Astro Devices introduces the Nexus DSC ($449.95), a digital setting circle computer for your telescope. The Nexus DSC unit features a database of more than 60,000 objects and can be expanded to up to 1.7 million objects via an optional Micro SD memory card. The unit displays information on a red OLED display that functions at very low temperatures, powered by an internal rechargeable lithium battery. Nexus DSC automatically detects and inputs the precise time and location with its built-in GPS receiver. The DSC can connect with most tablets, smartphones, and computers through an RS232 cable or via an optional Wi-Fi interface. The unit is compatible with ServoCAT and SiTech motor controllers and most planetarium software programs. Telescope encoders are sold separately. See the manufacturer's website for additional details.

Astro Devices
+61 402158680; www.astrodevices.com



ISLAND IMAGING Premier astrophotographer Rogelio Bernal Andreo has published his first book *Hawai'i Nights*, documenting his nearly month-long photographic adventure visiting the islands. This landscape-format book measures 8.27 × 11.7 inches and is divided into informal chapters based on the nights he spent snapping breathtaking photos of the night sky on each of the main islands. The book features more than 70 photos of famous Hawai'ian locations seen under the stars, many as two-page spreads. *Hawai'i Nights* is available as a digital download for $24, in paperback for $49, and in hardcover for $65. 115 pages, ISBN 978-0-9906763-2-4.

Deep Sky Colors
www.deepskycolors.com/hawaii-nights.html

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.

App-Powered

Noted amateur and professional astronomers share their 14 favorite celestial apps.

The app world has exploded in recent years, and as a result, an abundance of astronomy apps for smart devices crowd the Apple and Android app stores. For an amateur astronomer seeking the best tools in the field, the bounty can be bewildering.

Rather than undertake an exhaustive review of all the apps available today — a review that might already be out of date tomorrow — we decided to take a "word of mouth" approach. We asked around in our community, soliciting reviews from noted amateur and professional astronomers on the apps they use day in and especially day out. Instead of intensive descriptions detailing every tool's capabilities, we asked our contributors to focus on their favorite features that make each app stand apart. (Prices are subject to change.)

Read on for personal takes on 14 apps that are fun, handy, and often essential to practicing astronomy.

— ***Monica Young***

WEATHER

Scope Nights
$1.99
Egg Moon Studio
Apple iOS

In a single glance, see your observing forecast over the next several hours or nights.

Amateur astronomers may not control the weather, but at least we can plan for it. Several astronomy-oriented weather apps are available, but *Scope Nights* has become my favorite. The beauty of the program is that you don't have to interpret weather data: the app gives each night a rating of good, fair, or poor. Small but legible graphics show the night's general weather forecast, as well as details such as Moon phase and sunset and sunrise times. A color bar shows any potential change in conditions over the course of the night.

The app uses GPS to obtain your current location, or you have the option of entering it manually, before it downloads global and local forecast data. You can also access a global light pollution app to find local dark-sky sites.

While the app uses the same forecast services used in other apps, such as the NOAA's National Weather Service for the U.S., it does a fine job of summarizing the data in clear and understandable fashion. *Scope Nights* is the best $1.99 I've ever spent in astronomy.

— *Rod Mollise,* Sky & Telescope *Contributing Editor*

Astronomy

PLANETARIUM

SkySafari 4
($2.99, $14.99, or $39.99 for Basic, Plus, or Pro)
Simulation Curriculum Corporation
Apple iOS, Mac OS X, and Android

See what's in the sky tonight or take an adventure, like this trip into Alpha Centauri.

***SkySafari* is the 800-pound gorilla** in the world of astronomy apps. It wasn't the first planetarium program for smartphones and tablets, but it was the first to make a believer out of me. I didn't think you could squeeze a full-featured depiction of the night sky into a smartphone, and even if you could, I didn't believe it would be very usable.

This app changed my mind. To my surprise, *SkySafari* is not a compromise compared to desktop applications. All the usual elements are there: constellations, planets, the Moon, asteroids and comets, and tons of star clusters, galaxies, and nebulae. The top of the line *SkySafari Pro* actually exceeds the object counts of some PC and Macintosh programs; it includes more than 27 million stars and 740,000 galaxies.

SkySafari can even do some things computer programs can't. Hold your device at arm's length and the app will use built-in sensors to provide a real-time view of the sky behind it. (This trick is now common to most planetarium apps.) Most impressive, though, is the legibility of *SkySafari* on a small screen. The graphics are even better on a larger display, becoming a thing of beauty.

— *Rod Mollise*

PLANETARIUM

Starmap Pro
($16.99)
Frederic Descamps
Apple iOS

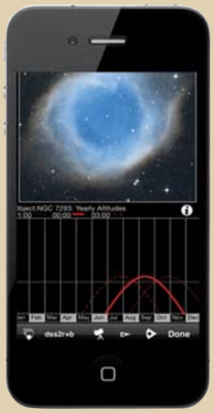
This planetarium program is customizable to your telescope's view.

Starmap Pro puts a capable planetarium program in the palm of my hand. It has all of the usual amenities, such as an extensive database (including 2.5 million stars) and an intuitive search function. *Starmap Pro* also tracks the real-time sky behind your device, helping you identify the celestial objects above you.

But its most powerful capability is an accurate depiction of my favorite eyepiece fields, and the ability to easily switch the eyepieces displayed. A twist of the wrist — flipping the mobile device over and back again — toggles the view between the eyepiece field and the sky map. This feature makes it one of my favorite apps.

— *Ted Forte,* Sky & Telescope *Contributing Editor*

PLANETARIUM



Deep Sky Browser ($9.99)
Astro Devices
Apple iOS

***Deep Sky Browser*'s catalogs and observing tools help you study deep-sky objects such as the Ring Nebula.**

Deep Sky Browser is the perfect companion to your print star atlas or the myriad of planetarium applications. The heart of this app is a database of more than 51,000 deep-sky objects drawn from a wide variety of catalogs. A tap of the finger brings up the Abell Catalog of Planetary Nebulae, Arp and Hickson galaxies, the Messier and Caldwell catalogs, the IC, ESO, and NGC objects, and even a complete listing of all 2,500 Herschel objects.

But easy access to a large database isn't the app's only selling point. Users can select objects according to apparent magnitude and download their images from the Digitized Sky Survey. (You can combine different filters to show a color image.) For each object, you'll find information such as its sky coordinates (RA, Dec), size, magnitude, surface brightness, and rise and set times. Accompanying graphs show its visibility that day and over the span of a year.

This program was clearly designed with the serious observer in mind.

— Richard Jakiel, astrophotographer and deep-sky and lunar observer

MOON

Moon Map Pro ($0.99)
Kari Kulmala
Apple iOS

I've been a fanatical Moon observer for years, so I've used a wide variety of printed lunar atlases in my time. Fortunately, it didn't take long for an amazing lunar atlas to enter the app scene. *Moon Map Pro* has two sets of maps, a relief and topography map covering the nearside (based on Clementine spacecraft data), and Lunar Reconnaissance Orbiter (LRO) maps that cover the entire Moon. The relief map has about 1,200 named features, while the beautiful LRO images show more than 8,000. You can flip or rotate the charts to match the view in your telescope. The app includes a few helpful tools, too, like a lunar libration calculator.

While I hope more features will be added in the future, *Moon Map Pro* continues to be one of my most-used apps.

— Rod Mollise

***Moon Map Pro* offers two versions of detailed charts. The Lunar Reconnaisance Orbiter provides this view of Cleomedes Crater.**

SUN

SoHO Viewer (free)
Jérôme Diaz
Apple iOS

***SoHO Viewer*'s simple interface puts multiple views of the Sun a finger tap away.**

As simple as this app is, you'll enjoy its features whether you are an armchair astronomer curious about our closest star or a dedicated solar imager. The app shows recent images taken by the Solar and Heliospheric Observatory (SOHO), presented in an 8-frame format. Updated on at least a daily basis, the images come in a variety of extreme ultraviolet wavelengths and also include a continuum (white-light) image and even a magnetogram. Two coronagraph images show a wider view of the Sun's coronal activity, displaying ejections of matter flying out from the solar surface.

With its frequent updates, I find this application especially useful in planning solar observing and imaging. Even watching the images change over a few days gives you an appreciation for just how dynamic the Sun really is.

— Richard Jakiel

EQUIPMENT

PolarAlign ($1.99)
George Varros
Apple iOS

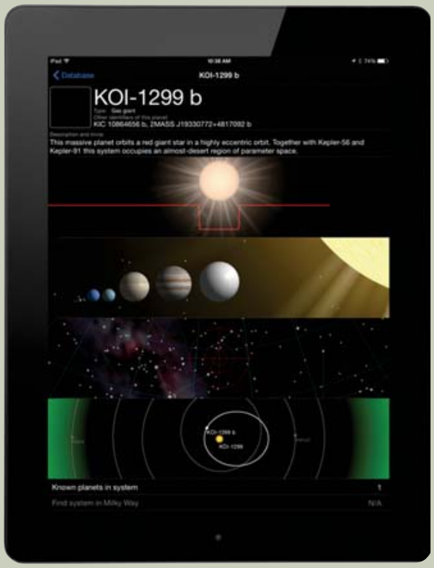
This straightforward little tool will help you improve your telescope's polar alignment for deep-sky observing.

The app is simple, consisting of a 24-hour Right Ascension circle similar to the one found in polar alignment scopes, with two reference circles: 2010 and 2020. Using your current time and location, the app gives the offset of Polaris from the true north celestial pole (or the offset of Sigma Octantis from the south celestial pole). You can adjust the intensity of the app's red-light view and choose the orientation to match that of your scope's view (inverted, corrected, or right angle).

Using this modest app has improved my polar alignment and reduced the setup time for deep-sky imaging.

— *Richard Jakiel*

PLANETS



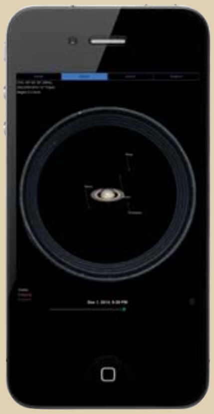
***Exoplanet* sends a notification with every discovery, then loads your device with all of the available information and observations.**

Exoplanet (free)
Hanno Rein
Apple iOS

Keep up with the breakneck speed of new discoveries in one of the most exciting areas of astronomical research. *Exoplanet* updates whenever a new planet is discovered, displaying its characteristics, such as mass, period, and size, its location and distance from Earth, the method of detection, and plenty more. Even better, the app links to all published scientific papers on the object in question, making the app a complete research tool.

— *Andrew West, assistant professor in the Department of Astronomy at Boston University, & Dr. Mario Motta, past president of AAVSO and telescope builder*

PLANETS



Gas Giants (free)
Software Bisque
Apple iOS

View our solar system's four largest planets and their major moons through a simulated telescope of your choosing.

This is a neat little app that shows the main features and larger satellites of all the outer giant planets, a useful app for planetary imagers and casual observers alike. For starters, the app shows the current and future visibility of the Great Red Spot, the tilt of Saturn's rings, the dance of the Galilean satellites, and even the fainter major moons of Uranus and Neptune. Scroll along the time slider to animate any giant planet and its moons 24 hours into the near past or future. The best feature: pick a telescope-eyepiece combination and simulate the high-power view through your scope.

— *Richard Jakiel*

ASTROPHOTOGRAPHY

NightCap Pro ($1.99)
Chris Wood
Apple iOS

***NightCap Pro* turns your smartphone's camera into an astro-imager. *S&T* equipment editor Sean Walker used the app to take this photo of the Moon.**

The iPhone has a nice built-in camera, so it's only natural that someone would eventually write an app to help take pictures in low-light conditions.

NightCap Pro allows users to take long exposures, capture night scenes, and even stack many frames to create star trail photos. The app includes some excellent features for those looking to toy around with astrophotography, such as focus lock, manual exposure, a self-timer, and adjustable noise reduction.

This handy app has permitted me to take some impressive iPhone shots of sunspots, lunar craters, Saturn, and even an early-morning conjunction.

— *Sean Walker,* Sky & Telescope *Equipment Editor*

PLANETS

JupiterMoons **($2.99)**
& *SaturnMoons* ($2.99)
Sky & Telescope
Apple iOS

The dancing retinue of Jupiter's and Saturn's moons enlivens our fascination with the solar system's gas giants. Amateurs have long relied on graphs and tables for moon positions, including those shown on page 51, but *Sky & Telescope* now has two convenient apps that perform the same function.

JupiterMoons focuses on the four Galilean moons, Io, Europa, Ganymede, and Callisto, while *SaturnMoons* features nine satellites: Titan, Rhea, Iapetus, Dione, Tethys, Enceladus, Mimas, Hyperion, and Phoebe (the latter a challenge even for large telescopes). The apps also accurately display the position of Jupiter's Great Red Spot and the tilt of Saturn's rings.

Each app opens with the moons in their current configuration, and easy-to-use controls let you plan ahead or explore the past in jumps of a year, month, day, hour, 10 minutes, minute, or second. You can even animate the display — the 10-minute interval works well if you want to watch the moons orbit their planet.

Essential to the *JupiterMoons* app is its table of satellite events, which lists moon and shadow transits, occultations, and eclipses. Click a table entry to see the view of Jupiter and its moons during the given event.

Other controls include night-vision mode, which turns the screen red, and buttons that flip/rotate the image to match the view through your telescope. "Learn more" buttons lead to extensive entries exploring the characteristics (and oddities) of each planet and its moons.

— Alan French, telescope maker and longtime observer

SUN

EclipseDroid **(free or $2.47 for full version)**
Wolfgang Strickling
Android

Thousands of skywatchers are willing to venture anywhere on Earth to witness a total solar eclipse. Paramount for any such trip is knowing exactly when and how long totality will last from a specific location, and how the Moon's traverse across the solar disk will look during the event. That's the predictive niche filled by *EclipseDroid*, a handy app developed by astrophotographer and self-professed umbraphile Wolfgang Strickling.

The app welcomes you with a sped-up animation of the next solar eclipse as seen from wherever your device happens to be. You can also change your location: select from an interactive map or a database of world cities or enter the latitude and longitude manually. Then touch "Eclipse details" to see the screen fill with specific times and sky (alt-az) coordinates for the event's key contact events, along with a plethora of other details.

Users of the free app have access to solar eclipse info from the recent past through 2015. The full version offers circumstances for events from 3000 BC to AD 3000. (The full version can be free too, if you download the app directly from Strickling's website.)

EclipseDroid also supports scripting that can, for example, step your USB-connected DSLR camera through a preprogrammed sequence of images while announcing a countdown in English, German, or Italian. But this app has its limits, excluding features, such as complex image sequences, that are available on desktop applications.

— J. Kelly Beatty, Sky & Telescope
Senior Contributing Editor

GENERAL

Astronomy Picture of the Day **(free)**
Concentric Sky
Apple iOS and Android

APOD shows a stunning new astrophoto every day, such as this Hubble Space Telescope image of the Cat's Eye Nebula.

This simple app is a worthwhile addition to any astronomer's smartphone. Updated daily, the app displays the famous Astronomy Picture of the Day, which often draws from current events in the astronomy world. Professional astronomers Robert Nemiroff (Michigan Technological University) and Jerry Bonnell (NASA Goddard) write most of the accompanying descriptions. The images are always spectacular and the explanations informative and written at an accessible level. ✦

— Andrew West

For links to all of the apps listed here, go to skypub.com/astroapps.

An Unobstructed Reflector

This off-axis telescope is built for high-resolution views.

MANY OF THE MOST interesting home-built telescopes come from ATMs who've already made a few instruments and are seeking new optical worlds to conquer. Jordan Marché is one such telescope maker. And his new world is a 6-inch, f/20 off-axis reflector — one of the more challenging optical configurations to attempt.

"I've been making telescopes, off and on, since 1970, starting with a short-focus 6-inch reflector," he says. Displaying a taste for the exotic and usual, his second instrument was an 8-inch f/25 folded reflector. Further down the road there was a 10-inch f/2 lensless Wright astrometric reflector, a 6-inch Cassegrain, and several other projects. Suffice it to say, an off-axis reflector isn't entirely out of character.

JORDAN MARCHÉ

Wisconsin telescope maker Jordan Marché has produced several interesting instruments over the years, most recently this unobstructed reflector. This conventional plywood Dobsonian-style structure houses a 6-inch f/20 off-axis optical train.

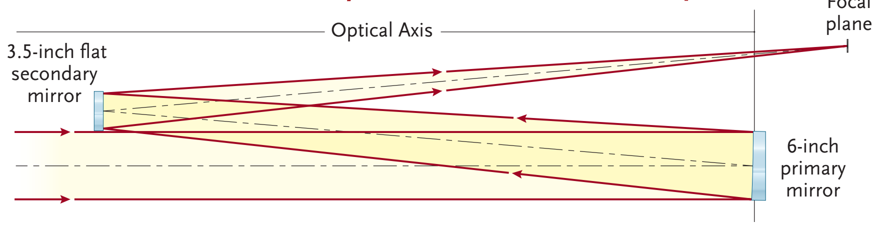
Jordan's experience with the 8-inch reflector provided a valuable lesson. "In some ways, that early instrument was a stepping stone," he recalls. "I knew about the diffraction effects of a 4-inch secondary mirror, and the off-axis design of my 6-inch is intended to overcome them."

Indeed, eliminating the effects of central obstruction is the chief virtue of the off-axis design. Unobstructed telescopes have long been something of a Holy Grail for telescope makers seeking the absolute pinnacle of performance, and there are numerous variations, each with its own strengths and weaknesses. Popular forms include the Yolo, Schiefspiegler, Buchroeder Tri-Schiefspiegler, and Stevick-Paul telescopes. Perhaps the simplest to execute is the off-axis Newtonian reflector.

The heart of Jordan's scope is its f/20 primary mirror, which can be thought of as a 6-inch-diameter section of a conventional 26-inch f/4.6 paraboloid. Indeed, coring a sub-diameter section from a "parent" mirror is one technique for making an off-axis Newtonian. Another way is to simply figure an off-axis paraboloid of the desired size, which is how Jordan proceeded.

Taking this route, however, is not for the faint of heart; producing an off-axis paraboloid is a significant challenge. As with a conventional Newtonian primary, you begin with a sphere that is subsequently modified to the desired figure, but with one crucial difference. "The edge of the mirror needs to be permanently marked, to indicate the direction of the optical axis," he advises. "This is because the center of the Newtonian parabola actually lies off one edge of the mirror in this design — something that must

6-inch f/20 off-axis reflector telescope



always be kept in mind!"

All mirrors require many repeated rounds of figuring, and testing. The trickier the optic, the more testing and figuring steps required. Jordan made two choices that helped a great deal. First was to employ autocollimation testing during the figuring process. This is a highly sensitive null test in which a perfect paraboloidal mirror grays out evenly, in much the same way a spheroidal one does in a normal Foucault test. With this arrangement, he was able to quickly read the mirror's figure to determine his next figuring step.

The second important factor was finding the right tool and figuring techniques. "There was a lot of trial-and-error involved," he says. "I tried a petal-shaped lap initially, but that didn't work out. I settled on a combination of offset strokes made with a normal, full-size lap to get the smooth, accurately figured surface required."

The other optical component of the scope is a 3½-inch-diameter secondary mirror. "I couldn't find a glass blank that size, so I made a 4¼-inch flat and masked it down to 3½ inches," Jordan says. While not as challenging as the primary, a flat this size isn't exactly a walk in the park either. Fortunately, he could draw on past experience having made several large flats before, including the one for his 8-inch folded Newtonian.

And how are the images? "The telescope provides very rewarding views of the moon and planets," Jordan reports. "It compares favorably with any scope of similar aperture, regardless of design."

Looking back over the scopes he's already made, I couldn't help but wonder what his next project would be. "I've already completed the perforated 8-inch optical flat and long-focus 6-inch primary for a Russell W. Porter-style fixed-eyepiece reflector," he replied. Somehow, that doesn't surprise me.

Readers wishing to learn more about Jordan's telescopes can reach him at jdmarcheii@gmail.com. ✦

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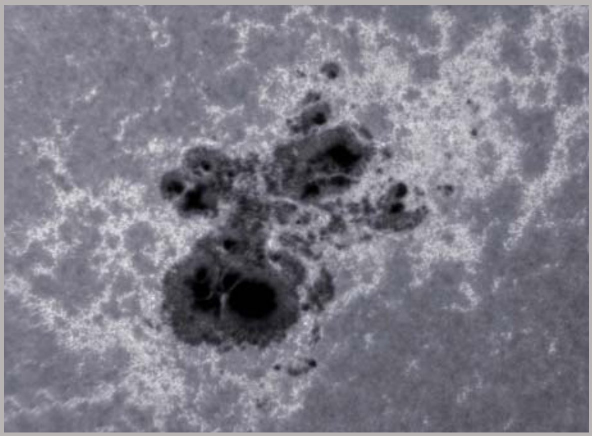
*Contributing editor **Gary Seronik** still has the unfinished optics for a Yolo sitting in a box awaiting completion. You can contact him via his website, **www.garyseronik.com**.*

Gallery showcases the finest astronomical images submitted to us by our readers. Send your best shots to gallery@SkyandTelescope.com. See SkyandTelescope.com/aboutsky/guidelines.

▶ **FULL OF STARS**
David Mittelman
Globular Cluster M13 displays countless yellow and blue stars in this deep image.
Details: *PlaneWave Instruments CDK20 telescope with SBIG STX-16803 CCD camera. Total exposure was more than 13 hours through Astrodon color filters.*

▼ **HOT ECLIPSE**
Brian Simpson
The partial solar eclipse of October 23, 2014 creates an evocative scene as it sets above the Detroit River.
Details: *Modified Nikon D90 DSLR with Hoya R72 filter and 70-to-300 mm zoom lens. Total exposure was 1/1000 second at ISO 200 recorded from LaSalle, Ontario, Canada.*



▲ **SUNSPOTS**

Chris Schur

Bright plages surround the large sunspot group AR 2192 in this calcium-K band solar image.

Details: *Stellarvue SV80 refractor with Lunt Solar Systems Calcium-K filter and Imaging Source DMK51AU02.AS video camera. Stack of multiple video frames.*

◀ **BLOOD MOON SERIES**

Greg Hogan

The Moon slowly enters Earth's shadow on the morning of October 8, 2014, seen at 10-minute increments over the course of an hour.

Details: *Sky-Watcher ProED 120 refractor with Canon EOS 7D DSLR camera. Montage of multiple exposures.*

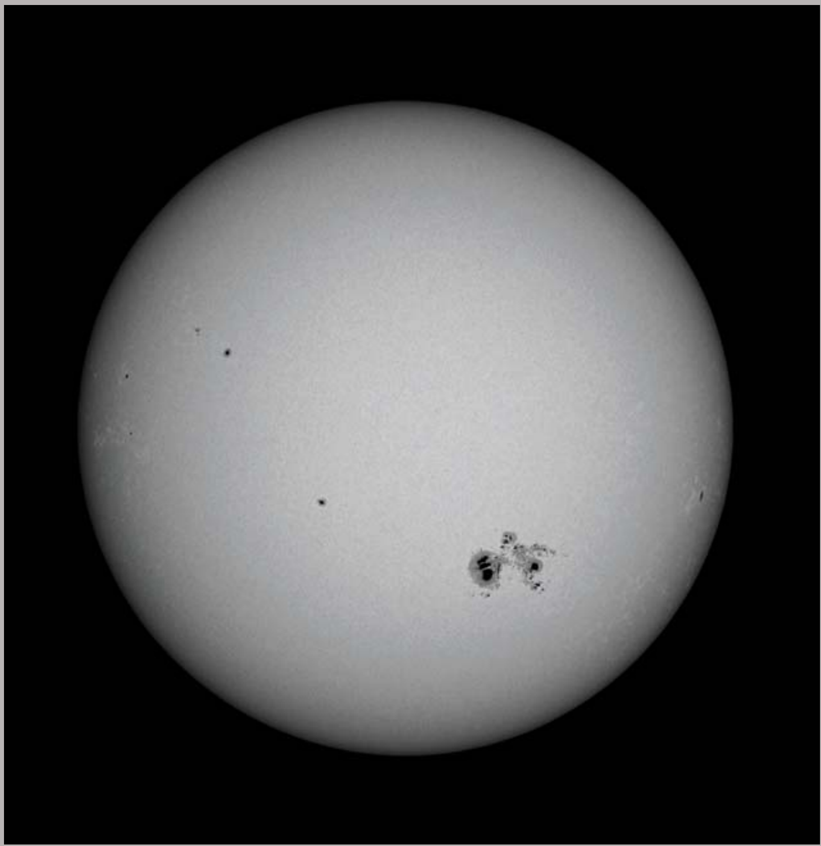
▲ **SOLAR ACTION**

Pete Lawrence

Massive prominences dance along the solar limb as seen on November 9, 2014.

Details: *Vixen FL102S refractor with Solarscope SF-70 filter, and a Lumenera SKYnyx 2-0 video camera. Stack of multiple video frames.*

NGC 7000
Terry Hancock
This expansive starbirth region in Cygnus features the North America Nebula at left and the Pelican Nebula (IC 5067) at right, separated by an extremely thick column of dust.
Details: *Takahashi Epsilon E-180 astrograph with QHY11 CCD camera. Total exposure was 3½ hours through color and Hα filters.*



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

◀ **SOLAR BLEMISH**

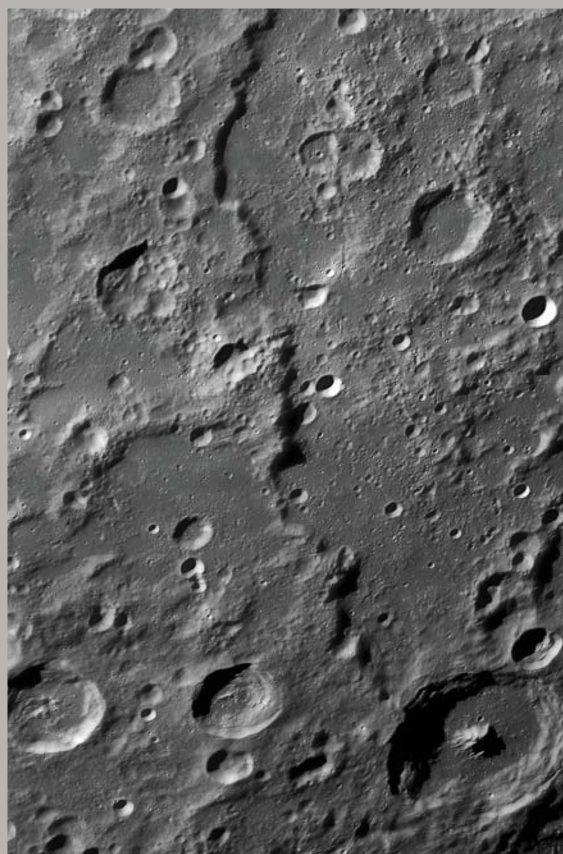
David Hanon

Sunspot grouping AR 2192 was easily the largest feature visible on the solar disk last October 31st.
Details: *Astro-Physics StarFire 180 EDT refractor with Canon 5D Mark III DSLR camera and Mylar solar filter. Total exposure was 1⁄500 second at ISO 100.*

▼ **RUPES ALTAI**

Paolo Lazzarotti

The long, jagged escarpment known as Rupes Altai delineates the southwest rim of the Nectaris Basin, terminating at the crater Piccolomini seen at bottom right.
Details: *Gladius XLI 16-inch Dall-Kirkham reflector with home-built Sony ICX285 CCD video camera. Stack of multiple video frames.* ✦



▲ **THE SQUID NEBULA**

Harel Boren

Recently discovered by French amateur Nicolas Outters, the extremely faint object OU4 in Cepheus is thought to be a nearby planetary nebula.
Details: *Officina Stellare Veloce RH 200 AT astrograph with SBIG ST-8300M CCD camera. Total exposure was more than 14 hours through color and narrowband filters.*

Market Place

Your essential source for astronomical products

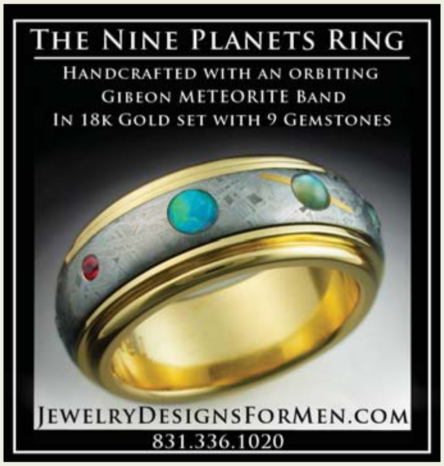
SKY & TELESCOPE

ACCESSORIES

BOOKS

COMPUTER SOFTWARE

MISCELLANEOUS



OBSERVATORIES / DOMES

OBSERVATORIES / DOMES

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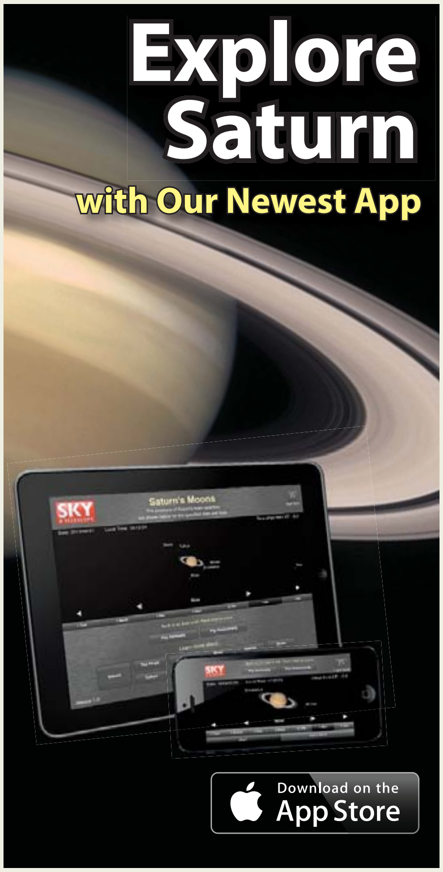

FOR SALE: Orion EON 120-mm f/7.5 ED Refractor OTA, aluminum case, tube rings, excellent condition. $1,200. 218-262-5114 (Minnesota).

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

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SKY & TELESCOPE

Inside This Issue

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

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Finger Lakes Instrumentation (Page 3)
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The Carob Tree

Or, planting seeds for the future

There is a story from the Talmud, the ancient Jewish text, of a young man walking down a road. He comes across an old man working under the hot sun, planting a carob tree. The young man asks the old man why he is planting the tree; surely the old man knows that he will be long gone before the carob will bear fruit. The old man replies that when he was young, there were carob trees bearing fruit and that someone must have planted them.

Astronomy has a way of touching us in a deep way: spiritually, religiously, and intellectually. Any way you look at it, astronomy is about our origins and our place in the order of things.

I am what you might call an advanced amateur astronomer. While I have a degree in the field, I've only practiced in minor ways professionally. However, my background gives me the tools to perform and interpret some relatively sophisticated observations with pretty simple astronomical equipment.

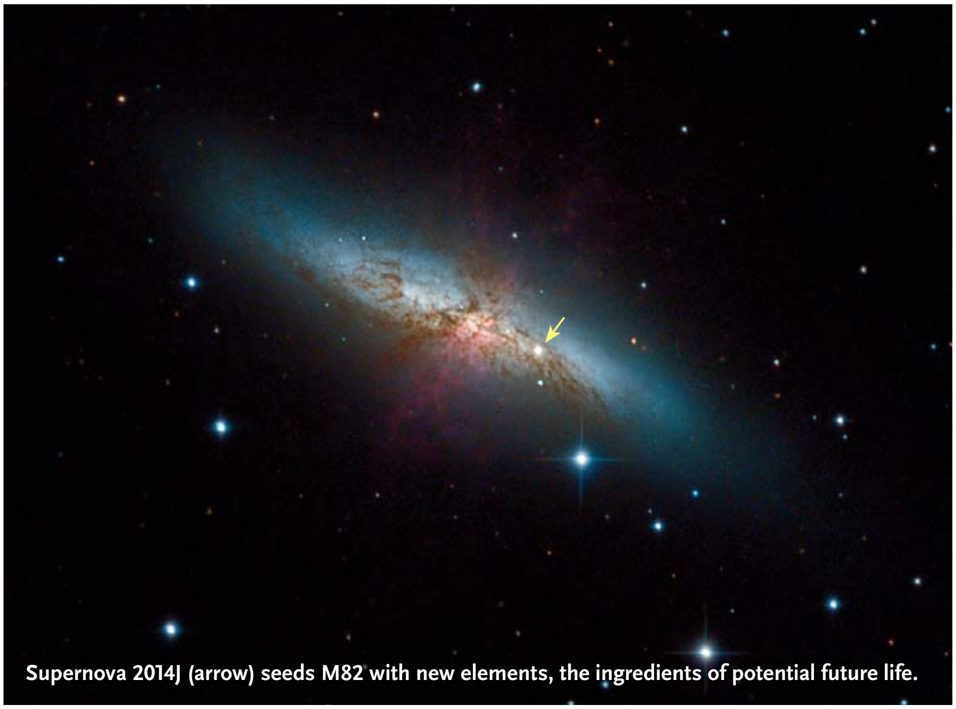
In January of last year, supernova 2014J erupted in the nearby active galaxy M82 in Ursa Major. It was the closest supernova in decades and as such was one of the brightest. I had recently acquired a low-resolution grating for spectroscopic imaging. With an 8-inch telescope I was able to take spectra over a period of two months and watch the evolution as the expanding shell of debris slowed.

Additionally, I could identify a number of lines in the spectrum, including the dramatic silicon line at 635 nanometers and numerous iron lines. I had read that supernova explosions produced iron and elements heavier than iron. I wondered: How much is actually produced? The answers I found in a literature search had significant uncertainties, but the important thing is the unit of measure: solar masses! Given that the Sun has a mass about 300,000 times greater than Earth's, this is a truly staggering amount of iron, not to mention other heavy elements, that each supernova heaves into the galactic environment.

Astronomy is not only a field of deep space; it is one of deep time. For me, the realization of how much iron a single supernova produces — enough to form hundreds of thousands of Earth-like rocky worlds or cores of gas giants — brings home the metaphor of the carob tree. Supernovae spread the seeds of future solar systems, future planetary systems, and future biospheres.

M82 lies about 12 million light-years away, so the explosion we witnessed last year took place 12 million years ago. Millions, perhaps billions of years in the future, its ashes will be incorporated into new worlds and maybe new life — just as our solar system formed billions of years ago, with life on Earth to come.

Just as the old man will never see the fruit of the carob tree he plants, our civilization and species will never see what fruit is born out of 2014J. But it is an assurance that the materials for continuing life are present in the unimaginably distant future in a faraway galaxy. For me, insights like these grant astronomy its profound allure. ✦



S&T: KELLY BEATTY / SEAN WALKER

Supernova 2014J (arrow) seeds M82 with new elements, the ingredients of potential future life.

Steven Hill *looks up at the stars through transparent Colorado skies from his home in Denver. During the daytime he helps monitor the Sun for NOAA's Space Weather Prediction Center.*

might·y /mī′tē/

(adj.) Possessing great and impressive power or strength, especially on account of size.

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