STELLAR SCIENCE: The Kepler Mission's Untold Legacy
PAGE 22

EXPLORATION: 65 Space Missions Across the Solar System
PAGE 16

BINOCULAR TOUR: The Hero & the Charioteer
PAGE 60

# SKY & TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY

## Make Your Nightscapes Epic
PAGE 36

## 30 Hot Products for 2018
PAGE 30

Is Our Sun Changing?
PAGE 18

January's Total Lunar Eclipse
PAGE 48

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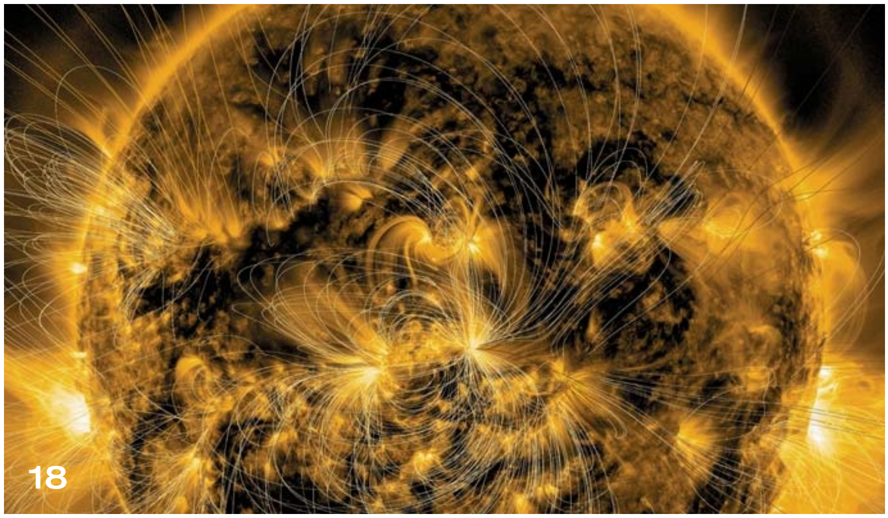
Ancient Astronomy: The Zodiac's Babylonian Origins
PAGE 66

CONTENTS

**SKY&TELESCOPE**
THE ESSENTIAL GUIDE TO ASTRONOMY

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# January 2018 VOL. 135, NO. 1

## FEATURES



## OBSERVING



## COLUMNS / DEPARTMENTS



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A 10-pane mosaic of McWay Falls in Big Sur, California
ROGELIO BERNAL ANDREO

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# Rippled Fabric of Astronomy

**ALL LAST SUMMER** few of us in the office could talk of anything except the spectacular event of August 21st. But in early fall the eclipse got eclipsed. For something to unseat the Great American Totality, it had to be a whopper, and it was (see page 10).

The fifth direct observation of the ripples in spacetime known as gravitational waves, announced on October 16th, shook up the field we report on like a bear whacking a beehive. A sizeable portion of the world's astronomers dropped everything to study its aftermath, and altogether, this single event in the galaxy NGC 4993 triggered a staggering amount of groundbreaking science:

•It's the first time astronomers have observed a cosmic event in both gravitational waves *and* light — in a sense, they both heard and saw it.

•It ushers in an entirely new era of "multi-messenger astronomy." Traditional astronomy has previously had only electromagnetic radiation to work with; now it has another "messenger" — gravitational waves.

•It provides further confirmation of general relativity, which predicts that gravitational waves should travel at the speed of light.

•It's the first time astronomers witnessed the merging of two neutron stars (the collapsed, incomprehensibly dense cores of high-mass stars).

•It validates the theory that such neutron-star mergers produce many elements heavier than iron, including gold, lead, and platinum, and spew them violently out into space, where they end up in places like Earth.

•It represents the first confirmed observation of a *kilonova*, which lies in luminosity somewhere between a nova and a supernova.

•It confirms the hypothesis that at least some short gamma-ray bursts — terrifically energetic blasts of radiation — originate in neutron-star mergers.

Not bad for an event that took place 130 million years ago in a far-off galaxy.

For more on these and other results, watch our next issue for a comprehensive feature by Contributing Editor Govert Schilling, author of *Ripples in Spacetime: Einstein, Gravitational Waves, and the Future of Astronomy*, published in 2017.

As for what this event has meant to astronomers, few said it better than Edo Berger of the Harvard-Smithsonian Center for Astrophysics: "It's hard to describe our sense of excitement and historical purpose over the past couple of months. This is a once-in-a-career moment — we have fulfilled a dream of scientists that has existed for decades."

The Royal Swedish Academy of Sciences might well agree, having awarded the 2017 Nobel Prize in Physics to three researchers deeply involved in the design of, and theorizing behind, the instruments that made all this possible.

Totality? What totality?

Peter

Editor in Chief



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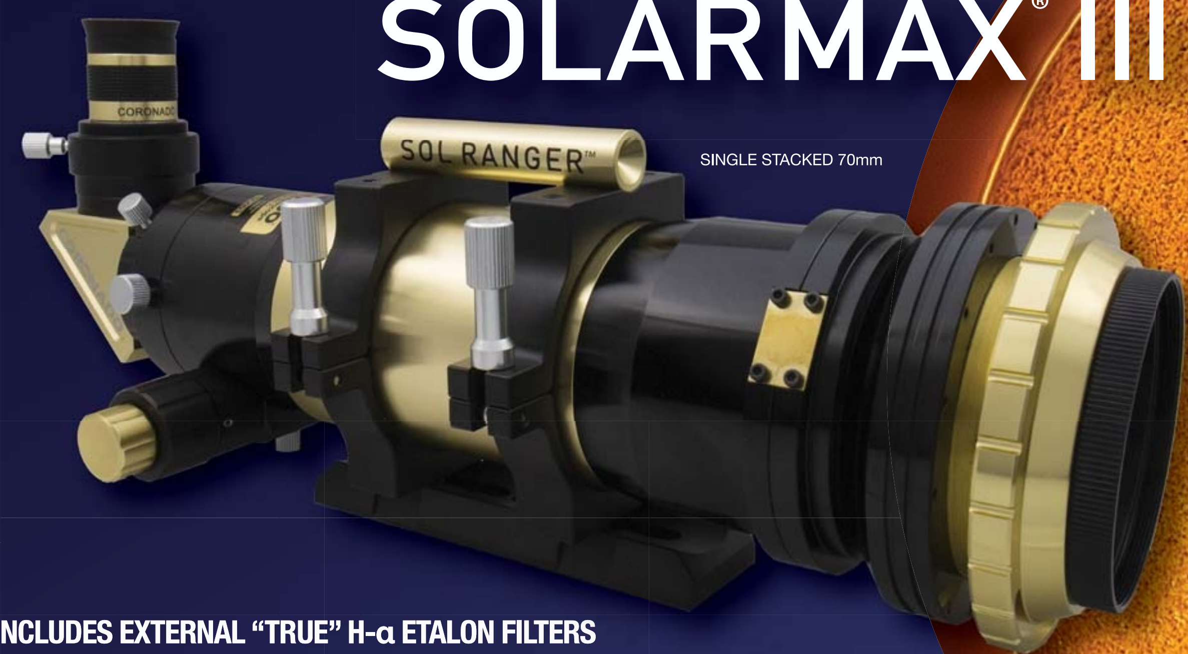


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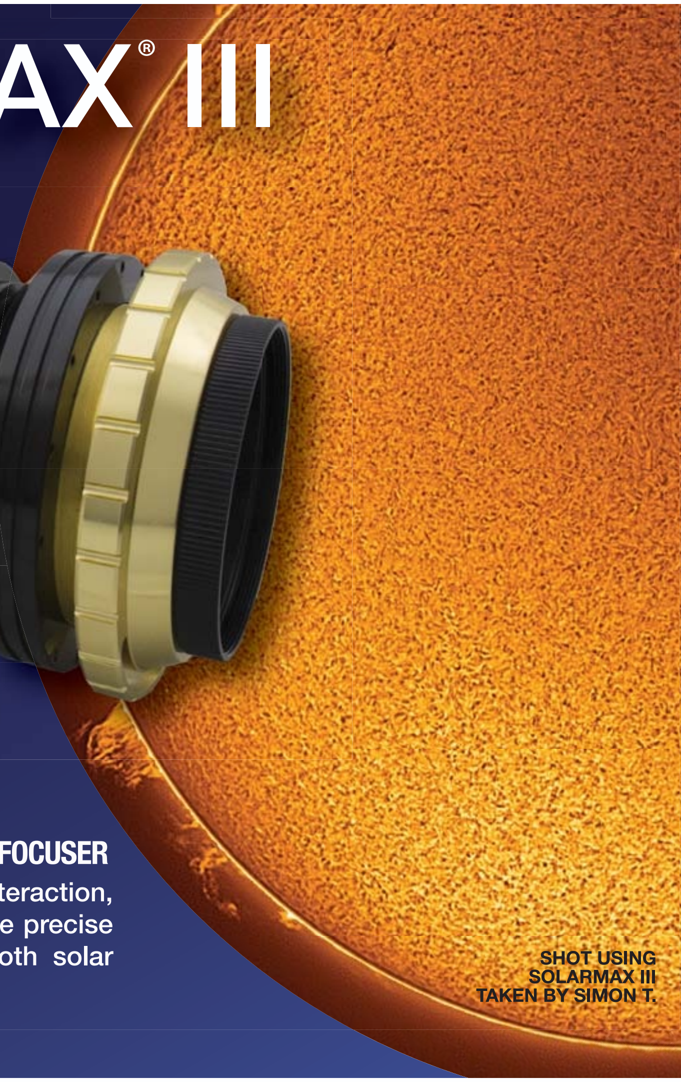

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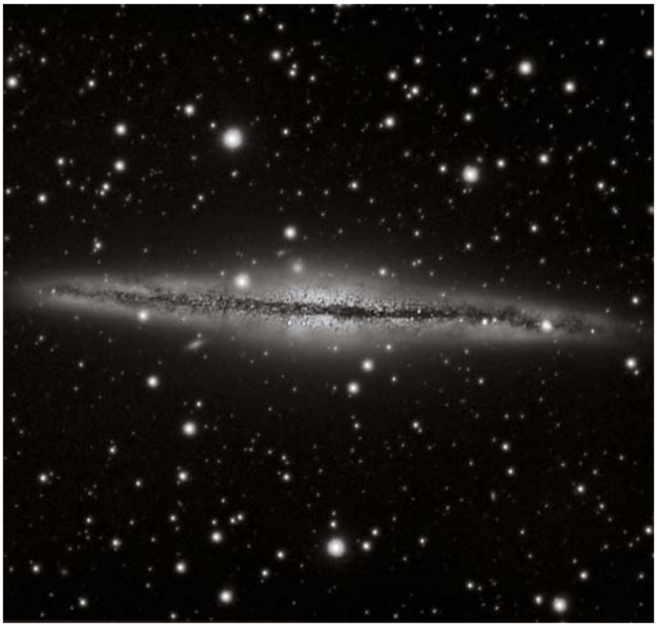


▲ Alessandro Falesiedi captured this detail in NGC 891, an edge-on galaxy about 13 arcminutes across, by combining 440 minutes of imaging data taken with an 11-inch-aperture telescope.

## NGC 891: An Accidental Fake

Regarding Jerry Lodriguss's article about astrophoto ethics (*S&T:* Sept. 2017, p. 66) and specifically an example involving my image of NGC 891, it is not possible in this small space to explain what really happened. However, the author could have at least noted, for the record, that in January 2017 I posted my version of the circumstances online, along with my raw imaging data: **https://is.gd/NGC891**.

For those who want to judge for themselves, all the necessary information is available there. Perhaps this will also provide some evidence to overcome preconceptions of the spatial detail achievable with the instrument I used.

I do not seek to mitigate what happened but instead to explain that this situation was unintended. Intentional plagiarism is something a beginner would do — and not worthy of those who have imaged for decades.

Behind every digital image, there is a human being made of flesh and feelings and — in my case — 30 years of astronomical observing, publications, and awards. In life you can go wrong, but not all mistakes are the result of criminal intent.

**Alessandro Falesiedi**
**Viterbo, Italy**

## Neutron Stars in Perspective

Feryal Özel's illuminating explanation of our abilities to measure and begin to analyze neutron stars (*S&T:* July 2017, p. 16) fills me with awe at the work of astronomers. Over millennia of study, they have built up a structure of the beauties of the sky that enables us to see and start to understand events at the very edge of comprehension and beyond. Maybe this very human effort says that we are not so small and insignificant in the face of the cosmos after all.

**Richard Gleason**
**Chicopee, Massachusetts**

## Dark Matter's Long Reach

August's issue contains two very well-written and interesting articles concerning "dark matter." One details Vera Rubin's conjecture (*S&T:* Aug 2017, p. 36) that dark matter or some unseen mass affects the rotation rates of individual galaxies. The other (p. 28) explores dark matter's role in the movement of many galaxies within a cluster. But the distances between galaxies are so vast — are these both due to the same physical phenomenon? Or is it possible that the two sets of observations require two different physical forces?

In the case of individual galaxies, the dark matter is believed to exist in a halo around the galaxy. But where is the unseen mass that Fritz Zwicky proposed to keep galaxies in the Coma Cluster from flying apart?

**Bob Rosenstein**
**Ellicott City, Maryland**

**Camille Carlisle replies:** Although the scales differ by a factor of 100, in both cases gravity is what's at work. We haven't found a convincing reason to think that gravity operates differently at these two scales, which is why for now we're sticking with the single explanation.

For both an individual galaxy and galaxy clusters, the dark matter is distributed in a big halo in which that galaxy or cluster sits. Look at the lead image for "In the Dark About Dark Matter" (pp. 28–29), and you'll see that matter in the cluster Abell 1689 (tinted blue) is spread throughout the vast conglomeration of galaxies. Baryonic matter doesn't match up with all that's there.

## Wanted: Early Issues of *S&T*

I'm creating a lecture presentation about the creation and early history of *Sky & Telescope*. Once I started digging deeper into this iconic magazine's all-important and significant formative years, I developed a true fascination for its origins. So I am seeking actual back issues from up to and including 1960. I'll add these to my library, both as research material and as publications to treasure and appreciate in their own right. If you have pre-1961 issues of *S&T* that you're willing to part with, please contact me with the dates of the ones you have and what payment you'd like for them. Use my email (**stars@starlight-nights.co.uk**) or my postal address (32 Myers Avenue, Bradford BD2 4ET, England). The condition of your issues is not paramount, though they do have to be complete. Hopefully I'll take them off your hands and give them a good home.

**Brian Jones**
**Bradford, England**

## A Special "Thank You"

I wish to thank David Levy for writing *Observing Variable Stars,* which I first read in 1992. That same year I joined the American Association of Variable Star Observers (**aavso.org**) and have been a member every year since. Janet Mattei, AAVSO's director at the time, mentored me back then, and I have enjoyed observing variable stars to this day.

I might never have read Levy's book had I not joined our local club, the Indiana Astronomical Society, the previous year. Since then I've remained an astronomy enthusiast generally, but I can't think of any better way to contribute to the science of astronomy than to observe variable stars.

**Mark A. Bradbury**
**Greenwood, Indiana**

## Seeing Double

A question occurred to me while reading "Eyes of the Dragon" (*S&T:* Aug. 2017, p. 22): Is there an official definition of an optical binary? In Matthew Wedel's article, it seems that neither magnitude nor separation is used in the definition. The pairings in his list range from 88.9 arcseconds apart (39 Draconis) to 15.4 *arcminutes* (Kappa Draconis). Yet all of the included pictures show the potential for dozens of other optical doubles (especially the illustration for 16 and 17 Draconis). Even more confusing, the optical doubles he highlights sometimes consist of two stars with Flamsteed numbers, with a combination of Flamsteed and Draper designations, or with one companion having no official designation at all!

**Phil Petersen**
**League City, Texas**

**Matt Wedel replies: If there's a standard designation system for optical doubles, it's news to me. If one could see deeply or widely enough, almost every star in the sky would appear surrounded by potential optical companions. The criterion I used in assembling the article's doubles was simply, "Did they catch my eye?" I'd be curious to find out whether a more formal identification system for optical doubles exists.**

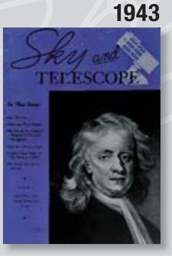
### FOR THE RECORD

● Due to production issues, a sketch of the Orion Nebula (*S&T:* Dec. 2017, p. 37) came out too dark. See the sketch in its full, vibrant form at **https://is.gd/HBM42**.

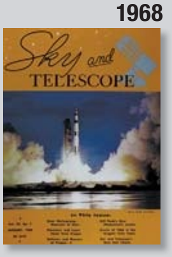
**SUBMISSIONS:** Write to *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140-3264, USA or email: letters@skyandtelescope.com. Please limit your comments to 250 words; letters may be edited for brevity and clarity.

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

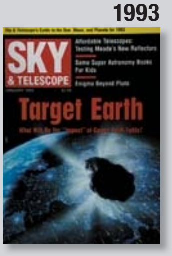
1943




1968




1993




◖ **January 1943**

**First Exoplanet?** "The system 61 Cygni remains in the limelight, owing to the interest of Dr. K. Aa. Strand, of the Sproul Observatory. Just a year ago he reported in this magazine on the first successful determination of the relative orbit of [this] famous double star. . . .

"[Now he finds] small periodic deviations [suggesting a third body with] about 16 times the mass of Jupiter, or 1/60 that of our sun. . . .

"Dr. Strand makes the suggestion that this invisible companion of 61 Cygni is a planet rather than a star. If so, this is the first instance of the discovery of planetary motion outside our solar system. . . ."

*Alas, this was the first of many false alarms. A half century would pass before astronomers confirmed the first exoplanets in 1992.*

◖ **January 1968**

**Eyeball Insight** "Nearly centered on the visual axis of the human eye is the shallow depression in the retina known as the fovea. . . . [E]xperiments by George Wald of Harvard University show that the very center of the fovea, its fixation area, is blue-blind because practically none of the numerous cones there are blue sensitive. . . .

"Dr. Wald (co-winner of the 1967 Nobel prize in physiology) advances an explanation for this property of the eye:

"'Unable to develop a color-corrected lens, the eye does the next best thing, and through a number of devices excludes or avoids using the short-wavelength radiation that would make the most trouble. . . .

"In the central retina, upon which the eye most depends for pattern recognition, the macular pigment begins to absorb just where the lens absorption falls off, and eliminates much of the violet and blue.'"

◖ **January 1993**

**Beyond Neptune** "The solar system got a little bit bigger last autumn [when] David Jewitt (University of Hawaii) and Jane Luu (University of California, Berkeley) initially picked up the faint, 23rd-magnitude object on August 30th while on patrol with a CCD camera and the 88-inch reflector atop Mauna Kea in Hawaii. . . .

"Confirmation of the discovery had to await the next dark of the Moon. Jewitt returned to the telescope on September 25th and again found [the object, provisionally called] 1992 $QB_1$. . . .

"Clearly, a solitary object in a distant orbit is no proof that an entire belt of material exists. But if 1992 $QB_1$ does turn out to have a circular or low-eccentricity orbit, it will add considerable weight to the Kuiper-belt hypothesis.

*Author Paul R. Weissman (then at NASA's Jet Propulsion Laboratory) cautiously tied 1992* $QB_1$ *to the belt of icy planetesimals beyond Neptune first envisioned by University of Chicago astronomer Gerard P. Kuiper in 1951. Today more than 1,800 of these "trans-Neptunian objects" are known.*


*Photographer: Carlos Guana*
*Camera: Canon 5D IV*
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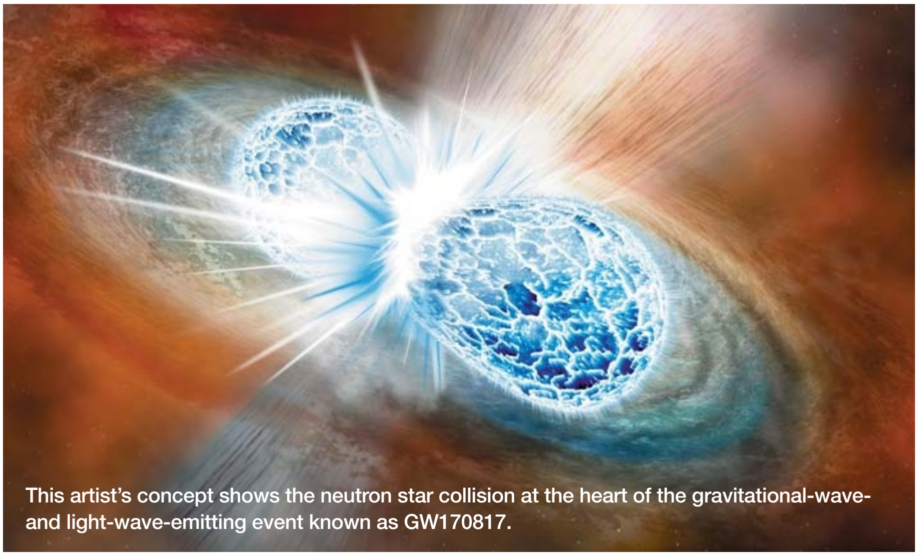


This artist's concept shows the neutron star collision at the heart of the gravitational-wave- and light-wave-emitting event known as GW170817.

# Two Massive Collisions and a Nobel Prize

**ASTRONOMERS HAVE** finally witnessed the collision of two neutron stars. On Thursday, August 17th, at 12:41:04 Universal Time, the two Laser Interferometer Gravitational-wave Observatory (LIGO) detectors bagged roughly 100 seconds' worth of spacetime ripples from the coalescing binary, an event now known as GW170817. Just 1.7 seconds later, NASA's Fermi Gamma-ray Space Telescope registered a 2-second blast of gamma rays from the same event.

Since the cosmic smash-up occurred near one of its blind spots, the Virgo detector in Italy — LIGO's European counterpart — didn't register a convincing gravitational-wave signal. Using LIGO's data and Virgo's weak detection, scientists triangulated the source of the ripples to an area of sky measuring just 28 square degrees, as they explained at an October 16th press conference.

What followed was a feverish hunt for an electromagnetic counterpart. Some 11 hours after the gravitational waves arrived, the 1-meter Swope Telescope at the Las Campanas Observatory in Chile discovered a optical source in the galaxy NGC 4993, 130 million light-years away in the constellation Hydra, the Water Monster. The 17th-magnitude optical transient changed color from blue to red within 48 hours, before fading away. By then, dozens of telescopes on the ground and in space, including Hubble, had studied the source.

Infrared spectra confirmed that the merger's rapidly expanding radioactive fireball produced huge amounts of heavy elements, probably including many Earth masses' worth of gold. The *kilonova* (*S&T:* Nov. 2013, p. 12) also generated X-rays observed by NASA's Chandra space observatory nine days after the event, as well as radio waves seen yet another week later by the Very Large Array in New Mexico.

Some 3,600 scientists from more than 900 institutions were involved in collecting and analyzing the wealth of observations of GW170817, described in more than 100 papers in many different journals. Look for an in-depth report on the effort and the scientific implications of the discovery in next month's issue.

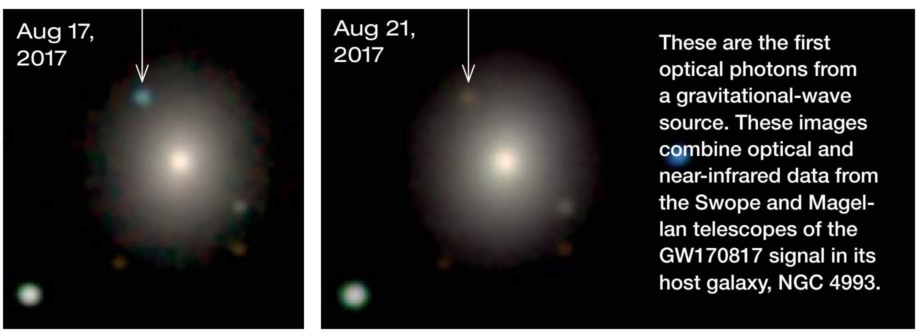
The neutron-star merger was actually the second gravitational-wave event "seen" by all three detectors since Virgo joined LIGO's second observing run on August 1st. In late September, the LIGO-Virgo Collaboration announced GW170814, which came from the collision of two black holes some 1.8 billion light-years away. The spacetime ripples from that event reached Earth on August 14th at 10:30:43 UT, just three days before GW170817.

In this earlier case, the original black holes weighed in at 31 and 25 solar masses before merging into a 53-solar-mass behemoth, radiating away the energy equivalent of 3 solar masses in the form of gravitational waves. Interestingly, these masses are comparable to those in two of LIGO's three earlier detections, GW150914 and GW170104, suggesting the previous events weren't outliers, says Gijs Nelemans (Radboud University, The Netherlands). If future detections confirm that masses tend to cluster in a narrow range of values, that could support different formation scenarios, he adds.

GW170814's localization was less precise (60 square degrees), due in part to the signal's shorter duration — 0.1 second, compared to 1½ minutes for GW170817. Counterpart searches were unsuccessful, which is unsurprising: Astronomers don't expect light from stellar-mass black hole mergers.

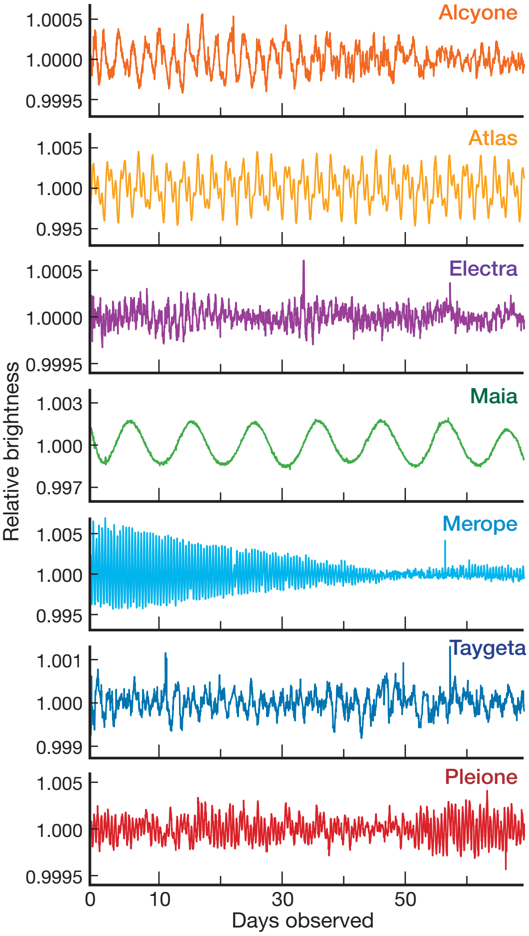
To recognize the gravitational-wave revolution, the Royal Swedish Academy of Sciences awarded the 2017 Nobel Prize in Physics on October 3rd to three of LIGO's principal contributors: interferometer inventor Rainer Weiss (MIT), former LIGO director Barry Barish, and theorist Kip Thorne (both Caltech).

**GOVERT SCHILLING**




These are the first optical photons from a gravitational-wave source. These images combine optical and near-infrared data from the Swope and Magellan telescopes of the GW170817 signal in its host galaxy, NGC 4993.

TOP: ROBIN DIENEL (CARNEGIE INSTITUTION FOR SCIENCE); BOTTOM: 1M2H / UC SANTA CRUZ AND CARNEGIE OBSERVATORIES / RYAN FOLEY




**STELLAR**

## Pulsations in the Pleiades

**THE EXOPLANET-HUNTING** Kepler spacecraft long monitored hundreds of thousands of distant stars with an exquisite sensitivity that — ironically — put the brightest stars out of its reach. But not anymore: Publishing in the November issue of *The Monthly Notices of the Royal Astronomical Society*, Timothy White (Aarhus University, Denmark) and colleagues tried out an innovative new technique known as *halo photometry* on Kepler observations of the brilliant "Seven Sisters" of the Pleiades.

CCD cameras capture photons in "wells," each of which corresponds to a single pixel in the resulting image. But a bright source can cause a well to overflow, saturating the central pixel(s) and creating a "bleed trail." White and colleagues instead measured brightness using photons recorded in the unsaturated pixels around the central one(s) and showed that this halo is a reliable measure of stellar brightness.

The seven brightest stars of the Pleiades are blue-giant stars brighter and more massive than the Sun, nearing the end of their short lives. As expected for this type of star, the new observations reveal that they all pulsate, slowly varying in brightness by less than 1%. Their light curves are shown at left.

Among them, Maia (20 Tauri) is unusual. It has a slow rotation and calm atmosphere, both of which allow unusual concentrations of heavy elements to circulate near its surface. Kepler observations reveal that Maia varies over an exceptionally long period, brightening and fading with a period of 10 days. The cause, the authors argue, is most likely a large, chemically enriched spot on its surface. If the spot is fixed, then it probably has some relation to the star's magnetic field, but more data are needed to learn how and why these chemical spots exist.

■ MONICA YOUNG

**EXOPLANETS**

## Heavy Metals in Hot Jupiter Atmosphere

**RESEARCHERS HAVE** found strong evidence of titanium oxide (TiO) in the atmosphere of hot Jupiter WASP-19b — a Jupiter-mass planet with a surface temperature of 2000K that orbits its host star in only 19 hours.

Just as ozone absorbs solar radiation in Earth's atmosphere, creating an inversion layer within which temperature increases with altitude, titanium oxide may play the same role in the exotic atmospheres around hot Jupiters. But while many astronomers suspect TiO's presence, actually detecting this molecule has proven difficult.

Artist's impression of exoplanet WASP-19b

As WASP-19b transited across the face of its star, Elyar Sedaghati (European Southern Observatory) and colleagues employed ESO's Very Large Telescope (VLT) to capture the star's light as it passed through a sliver of the planet's atmosphere. The air absorbs certain wavelengths depending on its chemical makeup. Analyzing the light captured by the VLT, the astronomers found strong evidence for the presence of titanium oxide in the atmosphere, accompanied by water and sodium, as well as a thick, light-scattering haze. The results are published in the September 14th *Nature*.

■ JAVIER BARBUZANO

PLEIADES GRAPHS: T. WHITE ET AL. / *MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY* 2017; EXOPLANETS: ESO / M. KORNMESSER

## IN BRIEF

### 7-Year Radio Survey Begins Observations

The iconic antennas of the Karl G. Jansky Very Large Array (VLA) have started scanning the sky as part of a new survey that promises the most complete map of radio-emitting celestial sources ever made. The VLA Sky Survey (VLASS) will require seven years of constant operation (a total of 5,500 observation hours) to cover 80% of the Earth's sky from its location in New Mexico's desert. It will scan the sky three times, each scan separated by about 32 months, which will enable astronomers to watch sources evolve, as well as to look for short-lived events. Data will be made publicly available as soon as they're acquired. Astronomers expect that the survey will find around 10 million new objects — four times more than currently known — including new supernovae, neutron-star collisions, and supermassive black holes.

■ JAVIER BARBUZANO

LUNAR

## Ancient Moon Had Volcano-generated Atmosphere

**ABOUT 3½ BILLION** years ago, active volcanoes on the Moon might have released enough gas to form a transient, sulfuric atmosphere.


Artist's concept of the ancient Moon's volcano-produced atmosphere

Intense eruptions that created the Moon's dark volcanic plains, or *maria*, might have released enough gas to create a thin atmosphere, a new study published in the November 15th *Earth and Planetary Science Letters* shows. This atmosphere may have survived for millions of years before being lost to space.

"The terrain would have looked like a sea of glowing molten rock, with patches of darker, cooling rocks forming a fractured crust on top of lava exposed to the developing atmosphere," says lead author Debra Needham (NASA Marshall Space Flight Center). "The atmosphere would most likely have been a brownish yellowish haze, due to the sulfur concentration."

This new vision of Earth's natural satellite comes from an improved analysis of gases trapped in the Moon rocks gathered during the Apollo mission, as well as detailed measurements of lunar features obtained by recent orbiter missions.

Researchers estimate that, at its peak, the lunar atmosphere was up to 1½ times as thick as that of present-day Mars, which has a surface pressure of 0.01 bar — equivalent to 1% of Earth's atmospheric pressure at sea level.

■ JAVIER BARBUZANO

### IN BRIEF

#### Webb Telescope Launch Delayed

The long-awaited James Webb Space Telescope (JWST) — successor to the Hubble Space Telescope — will now launch between March and June 2019. Integrating and testing various spacecraft elements, including the five-layered sunshield, is taking longer than expected and has forced a roughly 6-month launch delay from the original October 2018. The project will nevertheless remain within the budget that NASA agreed to in 2011. The telescope and its science instruments are currently undergoing extensive testing. The final step will be to integrate the telescope onto the spacecraft and test the fully assembled observatory before it is launched to orbit the Sun at the L2 Lagrangian point, 1.5 million km from Earth.

■ MONICA YOUNG

#### Hawai'i Approves Megatelescope

A state panel has cleared the way for the construction of the colossal Thirty Meter Telescope (TMT) atop Mauna Kea. The Board of Land and Natural Resources (BLNR) for the state of Hawai'i announced its decision on September 29th, after nearly five months of public hearings. An earlier BLNR ruling had also approved the $1.4 billion project, but it was a controversial decision among indigenous Hawaiians, who consider the mountain sacred. Construction ground to a halt in 2015 after a string of protests blocked access to the mountain's summit. The recent ruling specified 43 special conditions for TMT's construction, including environmental protection standards and an agreement to decommission and remove several existing telescopes from atop Mauna Kea. Opponents nevertheless plan to appeal the BLNR's latest decision to the Hawai'i Supreme Court.

■ J. KELLY BEATTY

#### First Official Pluto Feature Names

The International Astronomical Union (IAU) has released official names for 14 geological features on Pluto's surface, which were captured in high resolution during the New Horizons flyby in 2015. The names follow four broad themes: pioneering space missions, historic explorers who crossed new frontiers, scientists and engineers who contributed to our knowledge of Pluto and the Kuiper Belt, and underworld mythology. The first officially approved feature names are: Tombaugh Regio, Burney Crater, Sputnik Planitia, Tenzing Montes, Hillary Montes, Al-Idrisi Montes, Djanggawul Fossae, Sleipnir Fossa, Virgil Fossae, Adlivun Cavus, Hayabusa Terra, Voyager Terra, Tartarus Dorsa, and Elliot crater. There is no word yet from the IAU as to when additional features will receive official recognition.

■ JAVIER BARBUZANO

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

BLACK HOLES

## Supermassive Tango

**NEW OBSERVATIONS** reported in the October 2017 *Nature Astronomy* reveal a double radio source at the center of Markarian 533 (NGC 7674), a face-on spiral galaxy in Pegasus. The emission might come from a tight pair of supermassive black holes.

Preeti Kharb (National Centre for Radio Astrophysics, India) and colleagues used the Very Long Baseline Array to resolve two sources at a frequency of 15 gigahertz, which might emanate from two supermassive black holes with a combined mass of 40 million Suns. The putative pair orbit each other only a light-year apart, the closest candidate black-hole binary to be detected via direct imaging.

However, since the VLBI observations only detect the double source at a single frequency, the spectra are not yet known, making it difficult to rule out alternatives. It's possible, for example, that one source is a black hole, while the other is the base of a jet rather than a black hole companion.

But some factors, including the unusual Z shape of the galaxy's stubby radio-emitting jets, favor the double-black-hole scenario. If future observations confirm the supermassive binary, it will provide an important perspective on how such systems form and evolve.

■ MONICA YOUNG

NASA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# Cosmic Communion

*Last summer's total solar eclipse provided a profound moment of celestial accord for millions of Americans.*

Eclipse-watchers in Charleston, South Carolina, on August 21, 2017

**LIKE MANY OF YOU,** I long ago caught the total solar eclipse bug, and I've joined eclipse expeditions to other countries to stand in the shadow, in awe, with my fellow converts. In addition to the always sublime totality, this offers an excuse for going new places, following curves inscribed on the globe by a cosmic airbrush, and meeting other devotees along the way.

Totality has always been hard to explain to those who've never experienced a total solar eclipse, so last summer I was excited by the prospect of so many friends and relatives, not to mention vast multitudes of deserving strangers right here in my home country, finally seeing what all the fuss was about.

One thing I didn't worry about was over-hyping it. In the run-up, one friend — a planetary scientist, no less — posted that she didn't see why everyone was so worked up about a total eclipse. Naturally, when probed, she revealed that she'd never actually seen one. Or rather, I should say, never "been in" one. What the uninitiated don't understand is that totality is not merely something interesting you observe at a distance, but something that happens all around you and inside you as well, transforming your inner and outer landscapes in surprising ways.

We astronomy fans are used to feeling connected to distant phenomena. The site of an open star cluster seen through a telescope moves us. Not everyone gets this, but for anyone who witnesses totality, the feeling of a deep concord is unavoidable, and certain truths that we know in our heads suddenly become apparent in our guts.

Our human senses are stubbornly resistant to the Copernican insight that we live on a celestial body and that the sky is a vast landscape in which we dwell. During totality we detect the motions of Earth, Sun, and Moon, giving us a direct feel for the kinetic geometry of our universe. A veil of delusion lifts when, during daylight, we briefly see the stars right where they always are. I'm also always struck by how close the Moon seems.

All this adds up to a moment of profound communion with the cosmos and our fellow humans. Afterward, you feel newly bonded with whomever you're with. It's an experience we should never take for granted.

The fact that we can appreciate this arises from a great deal of cosmic evolution: the violent origin of our planet and unusually large moon, evolution of life, then animal life, then intelligent life and, in the last few centuries, a scientific culture that can study the cosmos. All of that culminates in this experience and allows us to appreciate it with both our heads and our hearts.

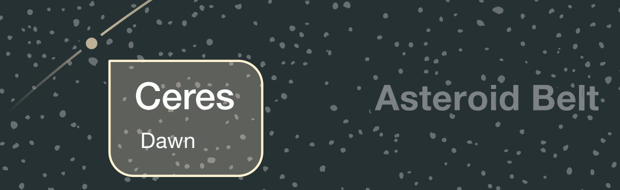
> For anyone who witnesses totality, the feeling of a deep bond is unavoidable, and certain truths become apparent in our guts.

There's the growing, creeping strangeness as totality approaches, when the light slowly thins, the colors become dreamlike, and the very air seems somehow transmuted. And then there's the intense, slightly frightening exhilaration of totality — the brevity adding to the thrill and the sense of time dilation. It really does cleanse the doors of our perception and put us into an altered state.

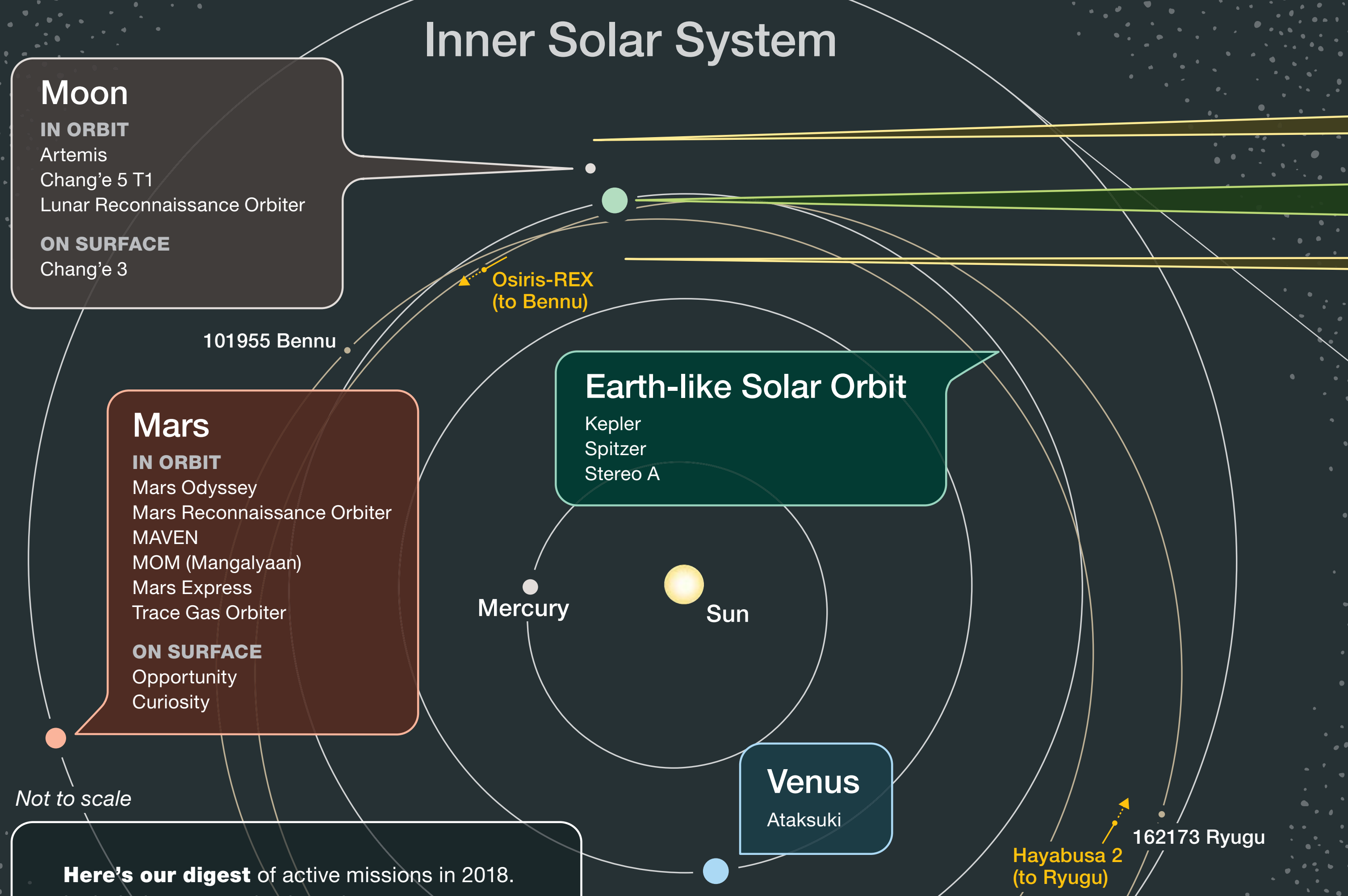
In my worldview, the scientific and the spiritual are melded in reverence for nature. There's no time I've felt more in tune with both than during a total solar eclipse. A group of friends and I are already contemplating a trip to Chile or Argentina in July 2019.

■ **DAVID GRINSPOON,** an astrobiologist, author, and musician, can be followed on Twitter as **@DrFunkySpoon**.

MANDEL NGAN / AFP / GETTY IMAGES




# Space Missions in 2018




**Here's our digest** of active missions in 2018. Included are astrophysics, planetary, gravity, solar, space weather, and stellar projects. Planet locations are for January 1st; mission statuses are current (to the best of our knowledge) as of October 2017. Those orbiting Earth are classified by primary research topic, which is subjective. (All International Space Station projects are lumped under "ISS.") Also included are planned launches for the year — but treat these as mutable.

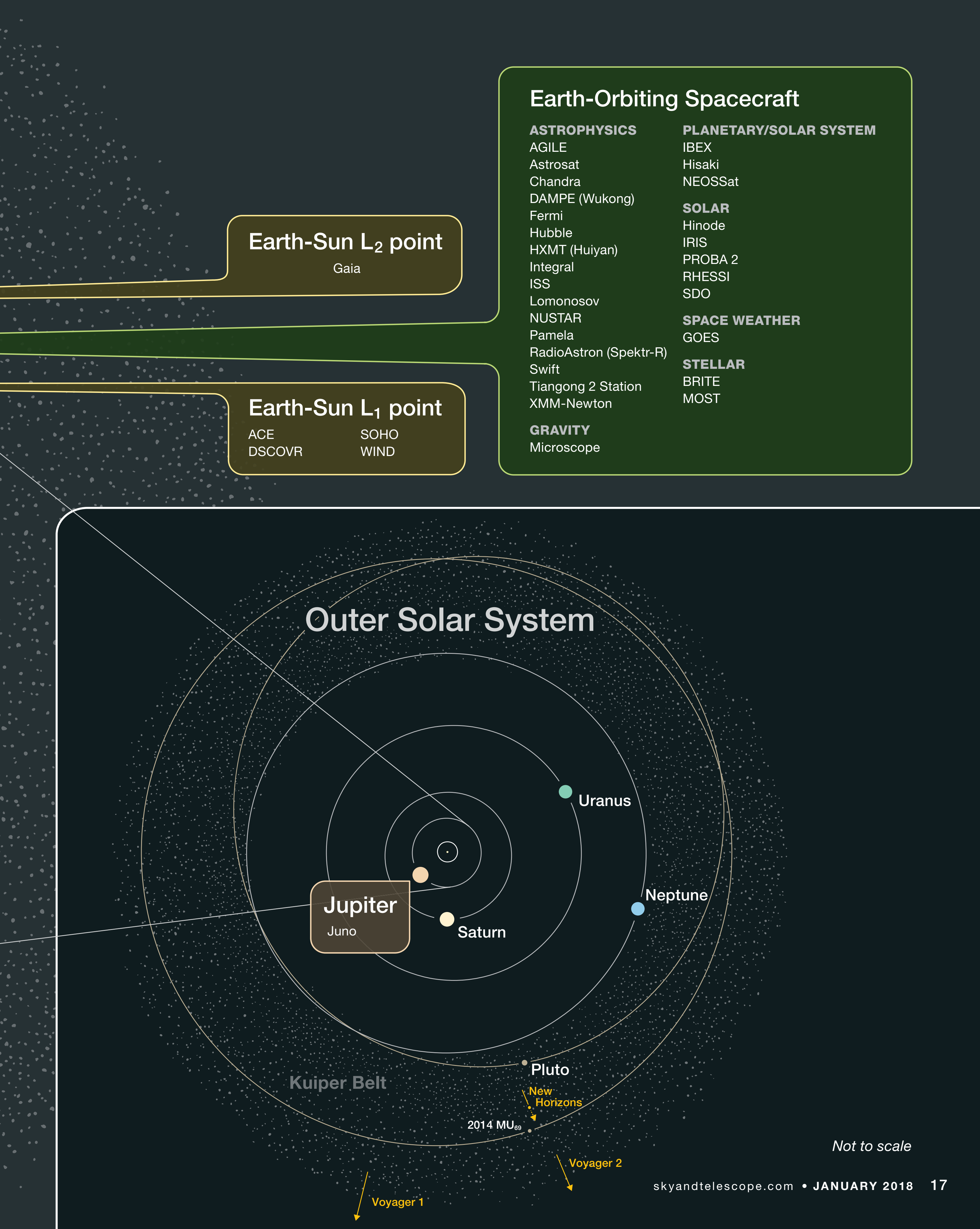
Projects studying the inner solar system and exoplanets nab many of the launches slated for 2018. Meanwhile, the sample-return missions Osiris-REX and Hayabusa 2 will both reach their target asteroids.

—Camille M. Carlisle

## Scheduled Launches, 2018

TESS *(exoplanets, Earth orbit)*
BepiColombo *(to Mercury)*
Parker Solar Probe *(to Sun)*
Cheops *(exoplanets, Earth orbit)*
Insight *(to Mars)*
Solar Orbiter *(to Sun)*
Chandrayaan 2 *(to Moon)*
Chang'e 4 *(to Moon)*
Spektr-RG / eRosita *(X-rays, to $L_2$)*

GREGG DINDERMAN / *S&T*


Earth-Orbiting Spacecraft
ASTROPHYSICS
AGILE
Astrosat
Chandra
DAMPE (Wukong)
Fermi
Hubble
HXMT (Huiyan)
Integral
ISS
Lomonosov
NUSTAR
Pamela
RadioAstron (Spektr-R)
Swift
Tiangong 2 Station
XMM-Newton
GRAVITY
Microscope
PLANETARY/SOLAR SYSTEM
IBEX
Hisaki
NEOSSat
SOLAR
Hinode
IRIS
PROBA 2
RHESSI
SDO
SPACE WEATHER
GOES
STELLAR
BRITE
MOST
Earth-Sun $L_2$ point
Gaia
Earth-Sun $L_1$ point
ACE
DSCOVR
SOHO
WIND
Outer Solar System
Uranus
Neptune
Jupiter
Juno
Saturn
Pluto
Kuiper Belt
New Horizons
2014 $MU_{69}$
Voyager 2
Voyager 1
Not to scale

# Is the Sun Changing?

Feeble sunspot cycles and other stars' behavior have prompted speculation on whether something's up with our Sun.

About 290 million years ago, a volcano erupted in what is now eastern Germany. The blast lifted trees straight out of the ground and coated them with liquid rock. Beneath this debris, an entire forest fossilized. Last year, scientists studied tree rings from these ancient trees — but not to learn about Earth. They wanted to learn about the Sun.

To the naked eye, the Sun looks like a uniform whitish sphere. But the solar surface is often mottled with dark spots, like the peel of a ripe banana. These sunspots emerge, live for a few hours or days (or longer), and then decay. Occasionally, 150 or more spots dot the solar surface. During those times, we observe many eruptions of high-energy radiation and, sometimes, superheated material, which can blast through space and hit the planets. At other times, hardly any spots show up at all, and the Sun stays fairly quiet. The Sun smoothly cycles between these two states, ramping the number of sunspots up and down every 11 years.

By studying fossilized tree rings, Ludwig Luthardt and Ronny Rössler (Chemnitz Museum of Natural History, Germany) made a striking discovery: The Sun has been going on like this for at least 300 million years. It's not that long on astronomical time scales — our Sun is, after all, 4.6 billion years old — but it means that some predictable mechanism operates inside the Sun, churning out cycle after cycle for millions of years.

But recent observations of the Sun and other Sun-like stars suggest that the solar cycle might eventually taper off and disappear. This controversial and speculative theory requires more observations, and calculations, before we can confirm it. But we can't rule it out, either. Is the Sun on the brink of a permanent change?

## The Cyclic Field

The Sun's cycle of activity originates in its magnetic field. Unlike the dipole bar magnets stuck to many refrigerators, the solar field looks like a giant hairball. It pokes out of the surface all over the place, creating sunspots. Each sunspot is a region of concentrated magnetic field. This field acts like a dam, preventing hot gases from flowing in. The location of these little magnetic dams, and the number of them, give us clues about the solar interior.

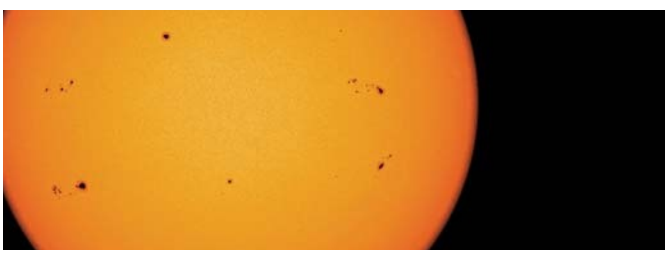
Solar physicists don't fully understand how the Sun generates its hairball magnetic field. They know that this field originates somewhere inside the Sun, due to the complex combination of various plasma motions in different regions. From there, the field moves outward, roiling around convective bubbles and forming braids, ropes, loops, and kinks. Finally, this twisted field pokes out through the solar surface, where we see it as a sunspot. For reasons that remain a mystery, sunspots appear closer and closer to the solar equator as the Sun moves through its 11-year cycle.

It is obvious, however, that the solar magnetic field governs this cycle. To study this process, scientists develop mathematical models of the solar magnetic field that reproduce the Sun's behavior. But we can also study the Sun by looking at other stars.

## Oddball Sun

The Mount Wilson Observatory sits atop a hill that overlooks the sprawling city of Los Angeles. Pine trees surround the dome, which, on a clear day, affords vistas of Catalina Island nestled in the shimmering waters of the Pacific. It was from this serene setting in 1966 that astronomer Olin Wilson used the 100-inch reflector to begin the first long-term study of spot cycles on other stars.

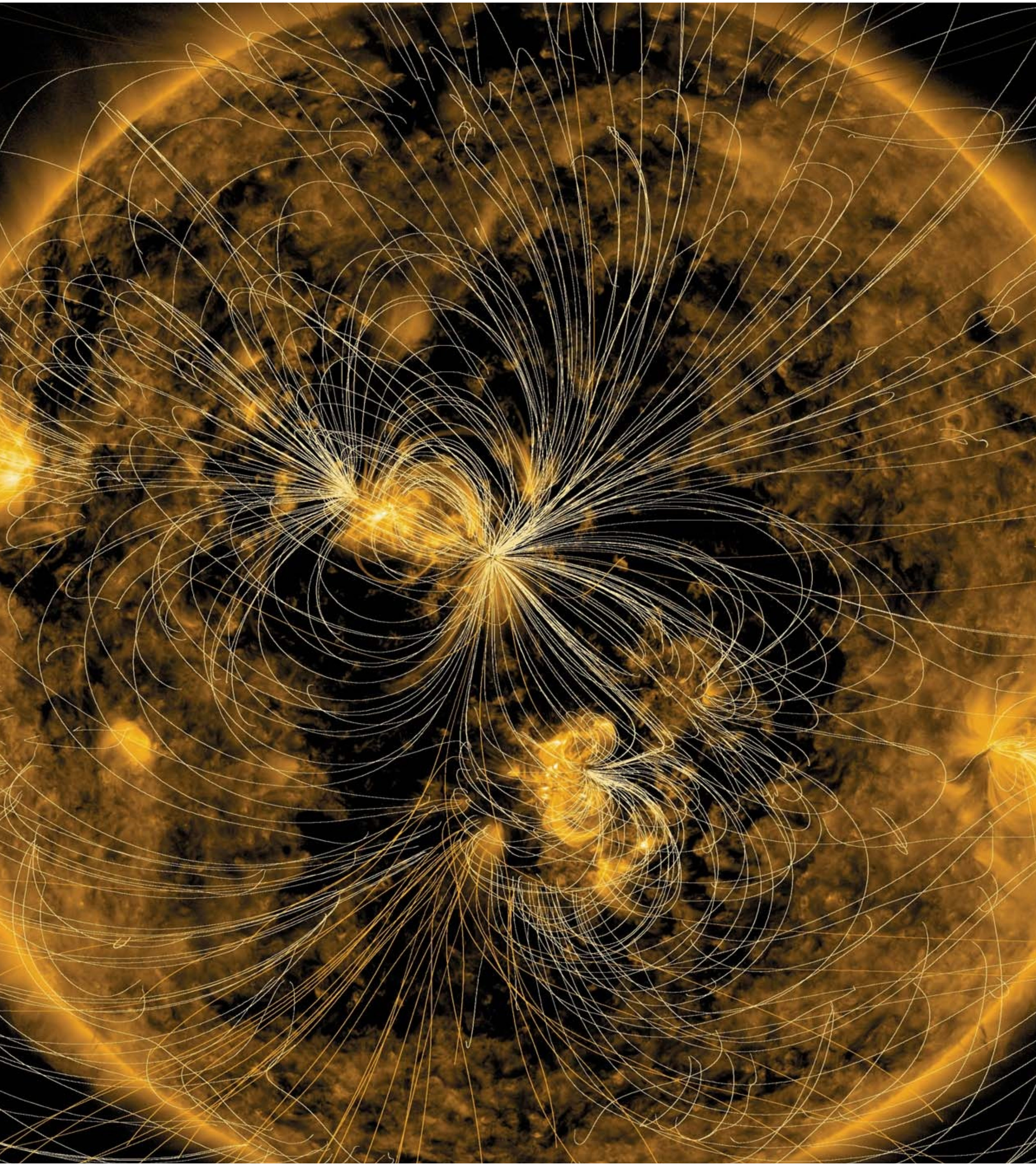
Wilson found spot cycles on all sorts of stars. Stars similar to the Sun (*G*-type) sported cycles, and so did ones slightly hotter (*F*-type) and cooler (*K*-type) than the Sun. On all these stars, the stellar magnetic field created spots and powered eruptions. From these data, it's clear that stars generate



◀ **SUNSPOT BANDS** Sunspots appear in two bands that sandwich the Sun's equator. At the beginning of the solar cycle they're high in the hemisphere (roughly 30° latitude), but as the cycle progresses the bands move closer to the equator.

▶ **SOLAR BALL OF STRING** The Sun's magnetic field is a complex, intertwined system that continuously rearranges itself. Shown is a magnetic field model overlaid on a picture from September 4, 2017, both from NASA's Solar Dynamics Observatory.

NASA / HMI / SDO; FACING PAGE: NASA / SDO / AIA / LMSAL

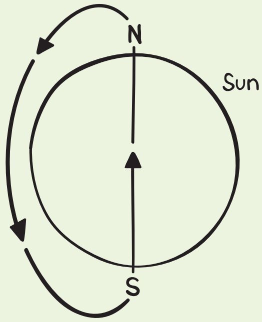


## HOW THE SOLAR CYCLE WORKS

By Monica Bobra

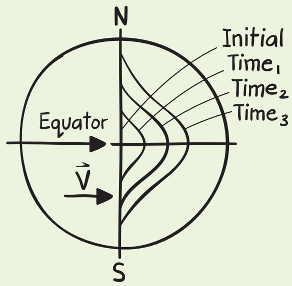
**1**

Start with a dipolar magnetic field. (This is a simplification.)



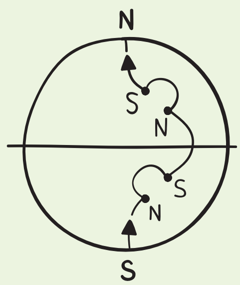

**2**

The Sun rotates faster at the equator than the poles. This *differential rotation* stretches out the field along the equator. (v is for velocity)



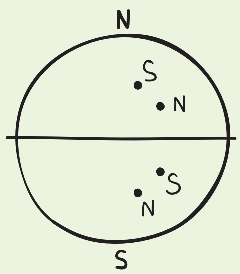

**3**

Solar rotation also twists the field into loops. When these loops poke up through the surface, we see them as sunspots. Sunspots usually appear in pairs, each with a north and south pole. (Note: The spot pairs are at an angle, and the higher footpoint has an opposite polarity as the hemisphere it's in. Important!)



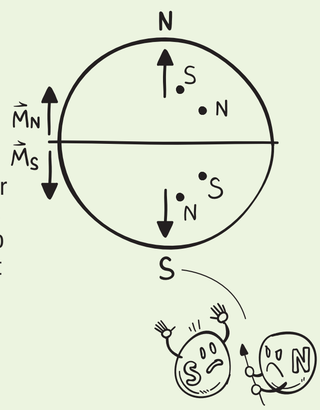

**4**

Most of the magnetic field cancels out quickly: Burbling plasma motions move sunspots around, and their magnetic field lines snap into new configurations. But these cancellations leave behind bits of magnetism. Think of them as sunspot debris.




**5**

Now another motion becomes important: the *meridional flow.* It slowly transports stuff toward the poles. It's also stronger farther from the equator. It drags the bits of opposite-polarity magnetism to the poles, where over time (about 11 years) they chip away at the Sun's polar field.




their magnetic fields using common processes that somehow create cyclic behavior.

But the way this cyclic magnetic field manifests itself from star to star is far from clear. Subsequent researchers discovered that stars in the Mount Wilson data fall into two rough classes: young, swiftly rotating stars with strong magnetic activity and cycles that last for 300 to 500 rotations, and older, more sluggish stars with less magnetic activity and cycles that last less than 100 stellar rotations.

One of the big problems with this picture is that it's based on a small amount of data. But this picture also caught astronomers' attention because it casts the Sun as the odd man out, sitting squarely in between both classes and producing a new cycle every 160 rotations. Some researchers decided to figure out why.

### Kepler Weighs In

Soon after Kepler launched from Cape Canaveral, Florida, on a clear night in March 2009, the mission made headlines around the world for its discovery of planets orbiting stars in the Milky Way. But Kepler discovered more than that. It also found hundreds of stars with starspot cycles.

A few months ago, Travis Metcalfe (Space Science Institute) and Jennifer van Saders (Carnegie Observatories) studied Kepler observations of *F*-, *G*-, and *K*-type stars to understand how the Sun might evolve over time. In the process, they unearthed other stars that didn't fall into the two groups from the Mount Wilson data.

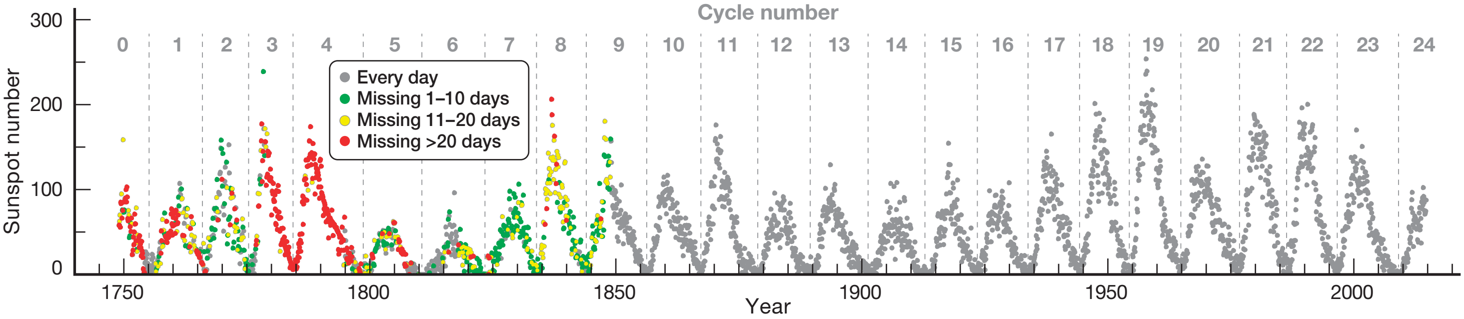
Perhaps, Metcalfe and van Saders reasoned, the Mount Wilson data don't describe two static classes of cycles, but rather two bookends of a star's evolutionary track. In this scenario, a star starts its life in the swift group, hits a critical turning point (which depends on a star's rotation rate and the depth of its convective bubbles), and experiences a weakening of its magnetic field, which transitions it to the other, sluggish group. Eventually, the field stops cycling altogether. In fact, maybe our Sun sits between these two classes because its magnetic field has already started to decay.

If so, this transition may take another 800 million to 2.4 billion years, according to Metcalfe and van Saders. During this period, the solar cycle will slow down. As it does, our familiar Sun — with dark, concentrated spots that appear and disappear over time — will change its look completely: Thanks to its steady field, it will wear a permanent coat of magnetic flecks like speckles on an egg. Eventually, the Sun, no longer an anomaly, will sit comfortably with its elderly companions.

It's an elegant theory, but not without controversy. Some worry we're seeing a relationship that, with more observations, we'll realize isn't there. Others think Kepler's sample may be biased, because Kepler can only observe cycles on stars with huge spots. Cycles on stars with tiny spots would go unnoticed by Kepler's detectors. Furthermore, the original Kepler mission's data only span four years — which means the space telescope couldn't detect cycles as long as the Sun's.

Luckily, solar observations go back much longer than that.

LEAH TISCIONE / *S&T*, SOURCE: MONICA BOBRA




▲ **HOW SUNSPOT NUMBERS CHANGE WITH TIME** Scientists use monthly averages of the International Sunspot Number (shown), itself a statistical combination of many observations, to track the solar cycle. (The number of missing days from 1750 to 1818 might be an overestimate.) Dotted lines mark the approximate start of each cycle. As clear from the chart, the solar cycle's strength and duration vary on multiple time scales.

## Superficial Sun

The interior of the Sun pulsates as rhythmically as a human heart. Magnetic fluids swish around the solar interior at thousands of different frequencies. Pressure changes inside the Sun create these reverberations, just like pressure changes in the air create sound.

Rachel Howe (University of Birmingham, UK) and colleagues listened to these heartbeats to study the structure of the solar interior. In particular, they wanted to know why this last sunspot cycle was the weakest one in a hundred years (*S&T:* Nov. 2013, p. 10). Their stethoscope of choice was a series of ground-based telescopes called the Birmingham Solar-Oscillations Network.

Using 31 years of observations, they found that the structure of the Sun's surface layer, where sunspots form, changed markedly in 1994. Since then, far more tiny, weak sunspots have dotted the solar surface than before. And these spots live in the shallowest layer of the Sun, unanchored to deeper layers as in previous cycles. Perhaps, Howe's team speculated in 2017, the Sun's surface magnetic field is thinning and its magnetic activity is weakening, its cycle slowing down.

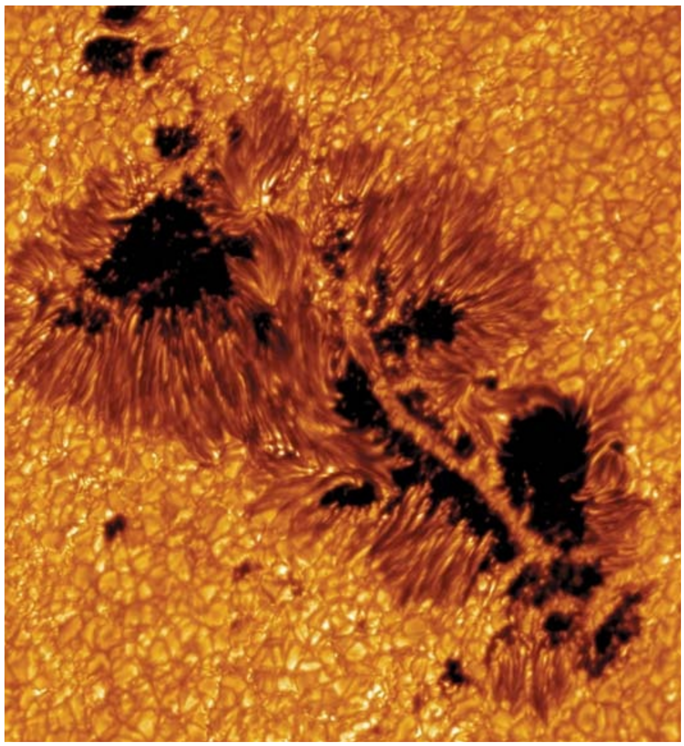
We still don't know whether this change is permanent or temporary. The Sun has deviated from its regular behavior before: The most famous example is a 70-year period in the 17th and 18th centuries called the Maunder Minimum, during which the Sun shed all but a few of its sunspots, only to resume its cycle again. But our star has done the same thing during the Spörer (1450–1540) and Dalton (1790–1830) minima. It might simply be doing it again.

## Enduring Mystery

Whether we're in a momentary lull or an everlasting decline, spot cycles can teach us about a lot more than the fate of our Sun. We can also learn about the fate of other planets. For example, scientists pore through data from Kepler and other, ground-based observatories, to search for exoplanets that might be able to support life. But determining a planet's habitability also depends on its host star. If a star plastered with spots releases giant flares, hundreds of times larger than the ones we see on the Sun, a planet in a habitable zone might not be so habitable after all.

In a few months, NASA will launch the Transiting Exoplanet Survey Satellite, which will observe nearly the entire night sky. Kepler, by contrast, only looked at a single patch of the Milky Way during its primary mission, and it can only observe along the ecliptic in its revitalized form (see page 22). With many more nearby stars to observe, we'll undoubtedly learn more about spot cycles. These data will help support, or quench, today's controversial theories. In the process we'll learn a little more about the star closest to home.

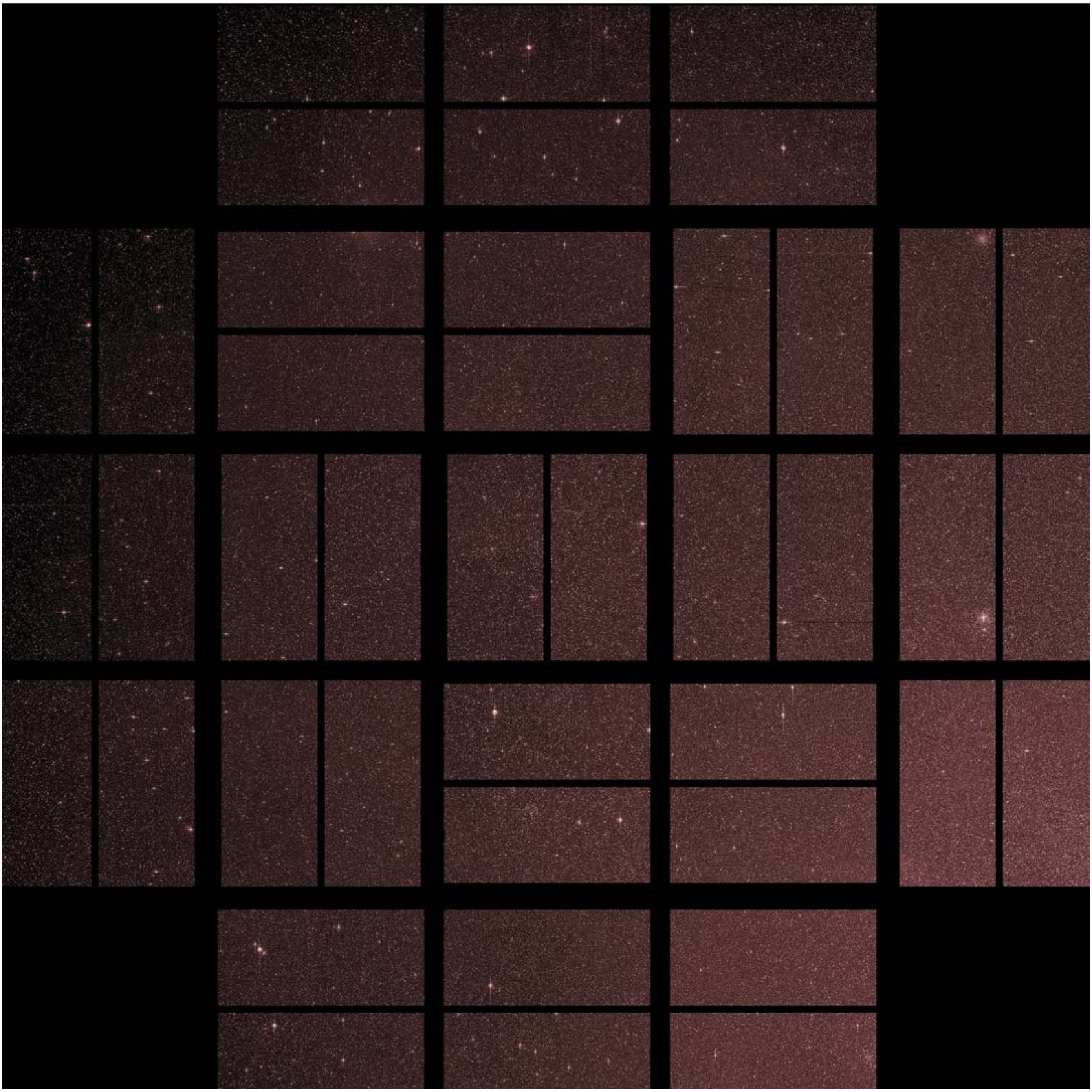
**MONICA BOBRA** is a solar physicist at Stanford University.



▲ **SUNSPOT CLOSE UP** Twisted, concentrated field lines poking out of the solar surface keep surrounding convective plasma (bright orange) from flowing into their locations, creating local cool spots that we see as sunspots. The widespread, bumpy cells are called *granules*; the feathery edges are the sunspot's *penumbra*, where magnetism leaks out to the rest of the surface.

GRAPH: GREGG DINDERMAN / *S&T*, SOURCE: DAVID H. HATHAWAY / *LIVING REVIEWS IN SOLAR PHYSICS* 2015; SUNSPOTS: THOMAS BERGER (LMSAL) AND MATS LÖFDAHL (ISP) / SWEDISH 1-METER SOLAR TELESCOPE

# KEPLER'S Unknown Legacy



NASA AMES / J. JENKINS

**The world's best planet hunter is also peering deep within stars, enabling astronomers to better understand how both stars — and the galaxy — evolved.**

"It was like opening up 53,000 presents for Christmas as a five-year-old," says Jon Jenkins, as he recalls a frenzied morning eight years ago. The Kepler space telescope, which had launched two months before, had collected data on 53,000 stars as one final check before the telescope entered its normal science phase. It was the first opportunity to see the telescope's raw images hot off the press and glean how well the telescope might actually perform.

And Jenkins (NASA Ames), the engineer in charge of Kepler's data analysis, was nervous. Despite being the first to arrive in the office around 6 a.m., he procrastinated with mundane activities like cleaning the communal coffee pot. When he finally did head to the science operations room to peer at the data, his anxious state quickly gave way to one of excitement. And by 10 a.m. he was surrounded by 20 or so colleagues, all of whom felt the same.

"Everyone was mesmerized by the data," Jenkins says. Although astronomers had seen plenty of light curves — plots of a star's brightness as a function of time — nobody had seen light curves as detailed as these. They were so precise that when Jenkins and his colleagues started emailing screenshots to colleagues who were off-site, many assumed that the team had monkeyed with them first or sent simulations. The raw images were simply too perfect to look like real data, Jenkins says.

"I was truly giddy after spending many hours perusing the light curves — I think we were all on cloud nine," Jenkins says. He had good reason to be. The light curves demonstrated that Kepler was going to be an indispensable instrument in the hunt for exoplanets. Indeed, by the time this story went to press in late 2017, Kepler had confirmed more than 2,400 exoplanets (see page 29). The finding demonstrates that exoplanets, even Earth-size ones, exist in abundance throughout the Milky Way Galaxy. Kepler has truly changed our perspective of exoplanets — and the potential for life — throughout the universe.

◀ **FIRST LIGHT** Taken on April 8, 2009, Kepler's first-light image contains approximately 4.5 million stars. Of these, team members selected roughly 150,000 as candidates in their search for exoplanets. The rectangles correspond to the telescope's 42 CCDs, together creating a 95-megapixel camera. The image brightens toward the lower right because that area lies closer to the galactic plane.

LEAH TISCIONE / S&T

But what Jenkins didn't know on that day in 2009 was that the planet-hunting scope was also going to revolutionize other areas within astronomy. Take stellar astrophysics. Kepler has peered into the hearts of Sun-like stars to show how they unleash huge amounts of radiation. It has disclosed the inner workings of stars that have swollen up to more than 100 times their original diameters. It has caught the early death throes of supernovae before any other telescopes. And these are only a few examples.

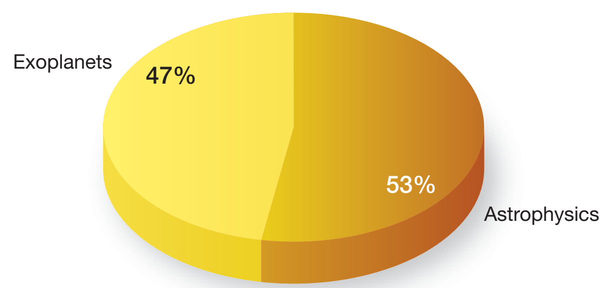
"There are not many fields in astronomy that Kepler has left untouched — and I think that's quite amazing," says Daniel Huber (University of Hawai'i).

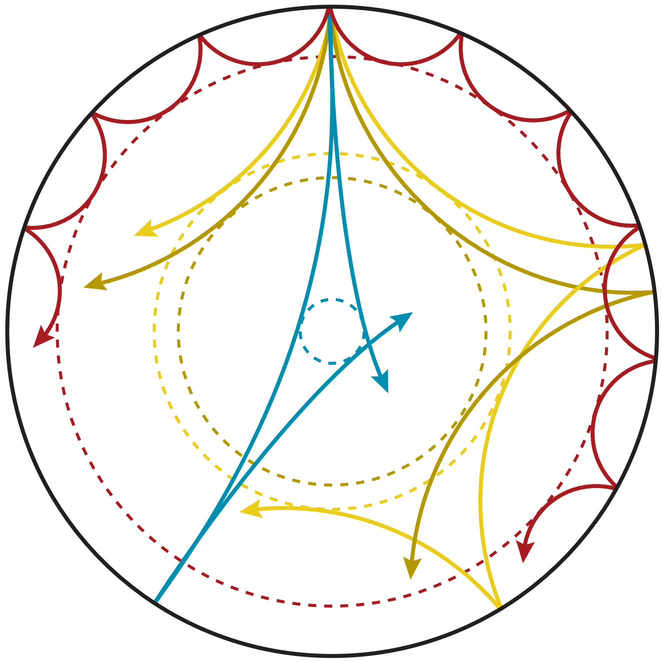
## Stellar Serendipity

Although many scientists were surprised by Kepler's stellar findings, there were some early scientists, like William Chaplin (University of Birmingham, UK), who understood that Kepler would be a game-changer for stellar astrophysics. That's because Chaplin planned from the beginning to use Kepler to listen to a celestial symphony.

A star's internal vibrations, triggered by the turbulent rise and fall of hot gases, will create sound waves much like those within a wind instrument. Those sound waves, in turn, cause the stars to oscillate (just like if you wiggle a bowl full of jelly, Jenkins says) in and out. These oscillations happen on many scales: Not only does the entire star "breathe" in and out as a unit, but smaller regions on the surface pulsate in more complicated patterns, expanding or contracting simultaneously and in some cases creating a checkerboard-like pattern across the surface. As the star breathes out, it grows bigger, cools down, and therefore dims. But as it breathes in,

**Kepler Papers (Both Missions), By Subject**





▲ **STELLAR SOUND** Acoustic waves take many paths through a star. The density and temperature of the plasma that the waves travel through influence the speed of sound, which changes the waves' trajectories and in some cases can even cause their paths to bend.

it squeezes the gas, making it hotter and brighter. As such, astronomers can "listen" to the stars by watching them brighten and dim from afar.

Chaplin likes to compare this stellar dance to inhaling from a helium balloon at a party. Our vocal chords vibrate when air passes through them. But if you flush out the air with helium, the sound waves move faster, making your voice resonate at a higher pitch. The same is true within a star. These celestial bodies are powered by a nuclear reactor that mostly converts hydrogen into helium. Because the sound waves will travel at different speeds through hydrogen- or helium-dominated patches within the star, astronomers can use the waves to peer deep into a star's heart.

So, in the same way that seismologists monitor earthquakes to study Earth's interior, so-called *asteroseismologists* can survey these oscillations to measure certain characteristics of a star, like its size, composition, age, and mass — all of which determine how the star wiggles.

"It's a surprisingly simple and elegant tool to learn a lot about stars that we wouldn't be able to know otherwise," Huber says. All you need is to observe the star's light curve. And Kepler is the ideal instrument for the job — so much so that Steven Kawaler (Iowa State University) says that if he had to design the perfect asteroseismology machine, it would be the planet-hunting scope.

Still, even those astronomers who understood that Kepler would be a boon for asteroseismology agree that the flood of incoming data and the number of breakthrough discoveries could never have been anticipated.

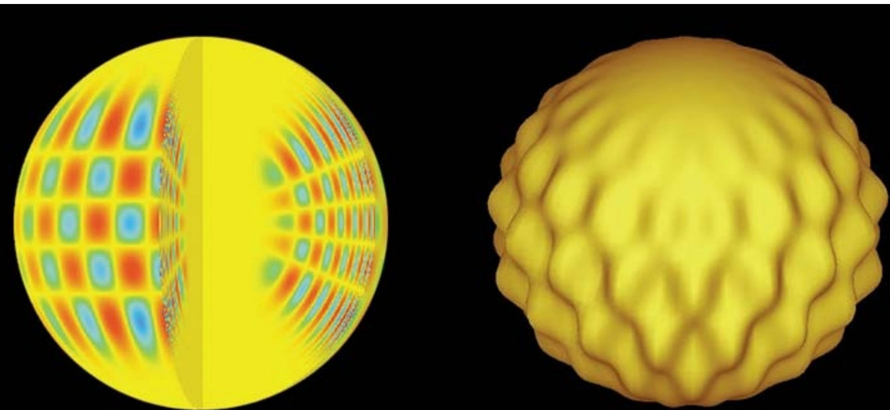
"We had no idea that asteroseismology would be revolutionized as much as it has been," Jenkins says. "It kind of falls in the shadows, unfortunately, of exoplanet discoveries, as wonderful as those are." Yet it has transformed what astronomers know about the structure and lives of stars, from results that suggest stars don't spin down terribly fast with age to others that pin down the exact mechanisms behind their final explosions.

## Stellar Storms

Although we have many satellites in space monitoring the Sun, they have only been able to do so for the last 55 years — a scale that's far too short to really gain an insight into a nuclear furnace that has been burning for 4.6 billion years.

So astronomers like Christoffer Karoff (Aarhus University, Denmark) are observing other Sun-like stars across their lifespans. And for that, asteroseismology has been key. Because astronomers can use Kepler to glean a star's mass, size, and age, they can then cherry-pick the stars that look exactly like the Sun in order to study how they behave.

The results have been unnerving. Although our Sun lives a relatively quiet life, occasionally sending weak waves of radiation toward Earth, some of the Sun-like stars imaged with Kepler are anything but peaceful. Instead, they emit



**ACOUSTIC WAVES** Simulated image (far left) of the acoustic waves resonating in a Sun-like star, with red and blue sections moving in opposite directions. These waves create a complicated pattern of surface displacement (near left), exaggerated more than 1,000 times for clarity in this illustration.

STELLAR SOUND: LEAH TISCIONE / S&T, SOURCE: SOI / STANFORD UNIVERSITY; ACOUSTIC WAVES (LEFT): ESO; ACOUSTIC WAVES (RIGHT): NASA MARSHALL SPACE FLIGHT CENTER *superflares* — giant blasts of radiation that are up to 10,000 times stronger than the strongest flares we've seen on the Sun (*S&T:* Nov. 2015, p. 22).

Such a flare would wreak havoc on any nearby planets. Take one of the most powerful solar flares in our history: In 1859, the Sun unleashed a gigantic flare and a storm of particles that rattled our magnetic field, causing auroras as far south as the Caribbean. But it was more than a beautiful event. It also caused a 5% reduction in our ozone layer — a significant loss in the barrier that protects us from the Sun's strong UV radiation.

"Had it occurred in the modern era, it would have been devastating," Kawaler says. Not only would it have crippled satellites, it could have also knocked out the power grid. But that flare was puny in comparison to superflares.

> Some of the Sun-like stars imaged with Kepler are anything but peaceful. Instead, they emit superflares.

The discovery of superflares raises the question: Will the Sun unleash one of these events in the future? Astronomers have long suspected that the longer the Sun evolves, the less we are at risk. Stellar activity should decrease with a star's rotation rate and therefore with increasing age, they've thought. Indeed, Kepler data show that young Sun-like stars that take 25 to 30 days to twirl around their axis will produce these mega flares, while older stars that take 50 days to twirl will not. The Sun currently falls in the first group.

Before Kepler, astronomers assumed the Sun would take another 2 or 3 billion years to slow down to half its current rotation speed, Karoff says, but new results complicate that. In 2016, Jennifer van Saders (Carnegie Observatories) and her colleagues used Kepler data to discover that older stars appear to spin faster than expected. How the Sun will slow, and what effect that change will have, is a mystery (see page 18).

Does that mean we should be preparing for a superflare? Luckily, no. Van Saders' team also discovered that the relationship between a star's stellar activity, rotation rate, and age breaks down once stars reach their mid-life point. "You get to a point where all of a sudden, there's a kink in that relationship," she says. So while older stars might spin faster than scientists previously assumed, their stellar activity still drops with age. As such, a solar superflare is not likely.

### Red Giants

Most agree that Kepler's biggest surprises concern later periods in a star's life. Once Sun-like stars exhaust all the hydrogen in their cores, they start to burn the gas that lies in a thin shell around this dense center. Then, as pressure increases, helium ignites within the core and begins transforming into carbon.

From the outside, it's clear that these stars undergo dramatic changes. They swell up to more than 100 times

## Some Non-exoplanet Hits

### Heartbeat Stars

If you map the brightness over time of certain stars, the result looks like an electrocardiogram. That's partly because these "heartbeat stars" are binary stars that shift shape — and therefore change in brightness — when they get close to each other in their orbit.

### Pumpkin Stars

NASA's Kepler and Swift missions helped discover a batch of stars that spin so rapidly they've been squashed into pumpkin-like shapes.

### Tabby's Star

The bizarre KIC 8462852 — sometimes melodramatically known as the "alien megastructure star" — flickers so erratically that astronomers can't settle on an explanation (*S&T:* June 2017, p. 16).

### White Dwarfs

Kepler revealed that pulsating white dwarfs, the cooling remnants of Sun-like stars, show unexpected behavior: They flare. But unlike on the Sun, where splicing magnetic fields create flares, these white dwarfs' outbursts seem to be tied to their pulsations.

### Dwarf Planets

In 2016, astronomers used data from K2 and ESA's Herschel Space Observatory to discover that 2007 $OR_{10}$ — a Kuiper Belt dwarf planet and the largest unnamed world in our solar system — is much bigger than previously thought (*S&T:* Sept. 2016, p. 10).

### Neptune

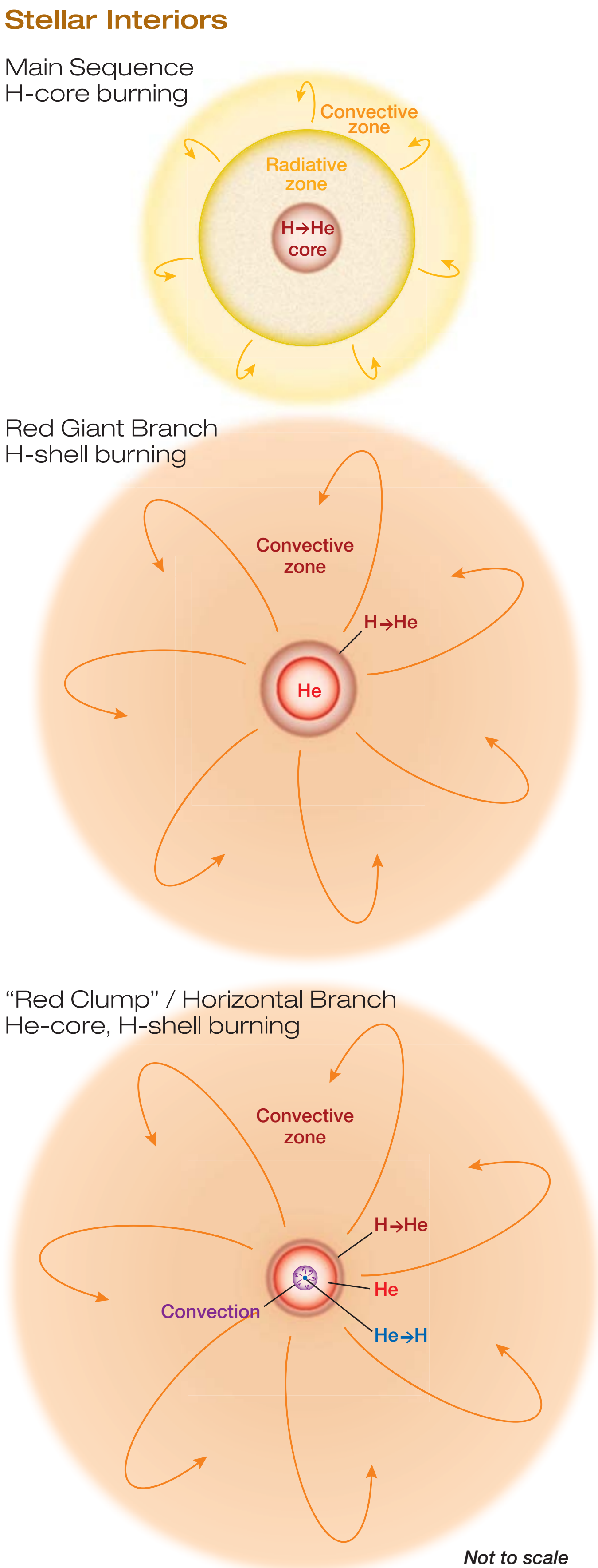
The K2 mission observed Neptune and two of its moons, Triton and Nereid, in one of the longest continuous studies of an outer solar system object.

### Asteroid Pairs

K2 observations of Jupiter's Trojan asteroid population suggest that about 20% of these little worlds are some sort of binary.

### Comet 67P

As the Rosetta spacecraft approached the end of its mission around Comet Churyumov-Gerasimenko in 2016, the comet slipped into the daylit sky, making it impossible to observe from Earth. During this time, Kepler gazed at the comet, providing crucial context for Rosetta's final close-up investigations.




their original diameters and glow orange-red. Betelgeuse, the prominent red giant at Orion's shoulder, displays a noticeable color difference compared with less evolved stars, even to the naked eye. But before Kepler it was impossible to distinguish between a red giant that is burning hydrogen in a thin shell and one that has ignited helium in its fiery heart. To an outside observer, they look exactly the same.

Then, Timothy Bedding (University of Sydney, Australia), and his colleagues reported that Kepler's red giants can actually be separated into two distinct groups. Kepler showed that they oscillate in one way if they're burning hydrogen in a shell around the core and in another way if helium has already ignited in the core.

"It is just an outstanding result," Kawaler says of the work. "Because that opens up the ability to test stellar evolution models along the giant branch in a way that we've never been able to before."

Those stellar evolution models play an important role in our understanding of other processes. "Stars are the building blocks of galaxies and hence whenever we study, for example, galaxy formation, galaxy evolution, and the evolution of our own Milky Way . . . it all hinges on our understanding of stars," Huber says.

But many mysteries remain, even some that impact the future of Earth — at least in about 7 billion years. That's when the Sun is slated to balloon into a red giant. Astronomers still don't know whether, when it grows to such a colossal size, it will merely distort the orbit of Earth or engulf the planet altogether (*S&T:* Oct. 2017, p. 22).

Another mystery concerns the giants' internal spins. Astronomers expected a red giant's core to contract as the star evolves, rotating more and more rapidly — think about a spinning ice skater as she pulls her arms in toward her. But Kepler has shown that the cores rotate far slower than researchers expected they would.

> "Galaxy formation, galaxy evolution, and the evolution of our own Milky Way . . . it all hinges on our understanding of stars."

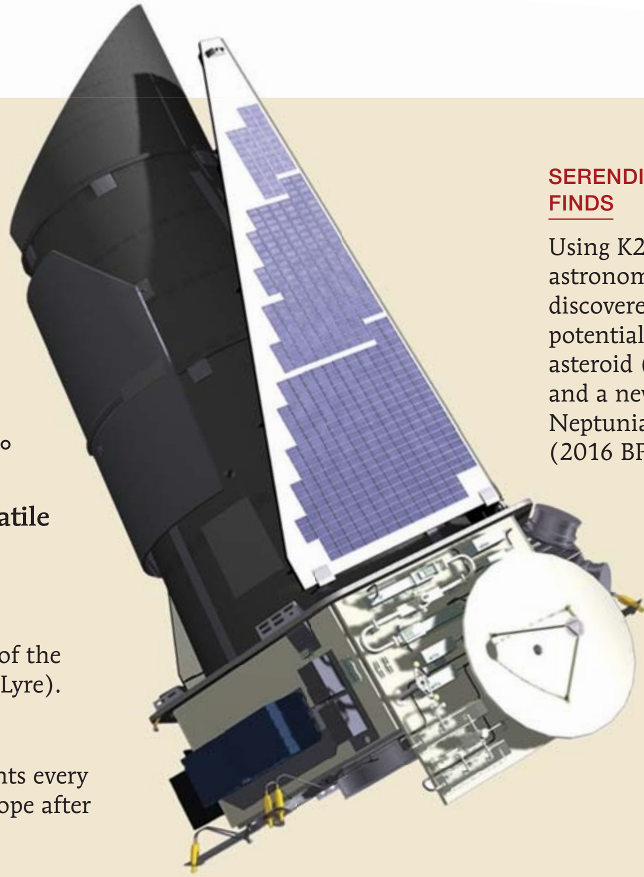
Rotation is one of the agents that transport energy inside a star and mix stellar interiors, allowing heavy elements to percolate outward from the star and then be released by large winds or supernovae explosions into the interstellar medium. There, they can fuel later generations of stars and even

◀ **STELLAR INTERIORS** Stars on the *main sequence* (including the Sun) fuse hydrogen into helium in their cores (top). Once this stage ends, stars continue fusion in a thin hydrogen shell around the core, producing more helium (center). Once the core hits critical temperature, the core helium begins fusing into carbon (bottom). Stars in the latter two stages are both called *red giants* and look pretty much the same from the outside, but Kepler data reveal that they oscillate in different ways, enabling astronomers to tell the difference between them.

GREGG DINDERMAN / *S&T* (3)

# Kepler by the NUMBERS

**Kepler's exoplanet-hunting prowess has been extraordinary: It has found 70% of the roughly 3,500 known exoplanets. But with a field of view spanning about 12° and an array of 42 CCDs, the 0.95-meter Schmidt space telescope has proved a versatile astrophysics instrument, too.**



### KEPLER

Kepler's primary mission stared in the direction of the constellations Cygnus (the Swan) and Lyra (the Lyre).

### K2

The secondary mission has to move where it points every ~80 days, due to issues with balancing the telescope after two reaction wheels failed.

### SERENDIPITOUS FINDS

Using K2 data, astronomers have discovered a new, potentially hazardous asteroid (2015 $BO_{519}$) and a new trans-Neptunian object (2016 $BP_{81}$).

## Astrophysics Observations

MICROLENSING EVENTS
>100
K2 campaign 9

GALAXIES
43,400

STAR-FORMING REGIONS
2

SUPERNOVAE
21

STAR CLUSTERS
21

### Our Solar System

SOLAR SYSTEM PLANETS
2 Uranus, Neptune

DWARF PLANETS
3

SOLAR SYSTEM MOONS
6
Includes Titan & Enceladus

COMETS
17

TRANS-NEPTUNIAN OBJECTS
57

ASTEROIDS
213
Doesn't count accidental observations

## Exoplanet Discoveries

NUMBER OF STARS OBSERVED DURING PRIMARY MISSION
>150,000

NUMBER OF CONFIRMED PLANETS FROM KEPLER
2,470

NUMBER OF POTENTIALLY HABITABLE WORLDS FOUND BY KEPLER
29 All methods: 42 Includes super-Earths and smaller

PLANETS THAT ORBIT SOLAR-MASS STARS
964

PLANETS THAT TAKE LONGER THAN 365 DAYS TO ORBIT THEIR HOST STAR
28

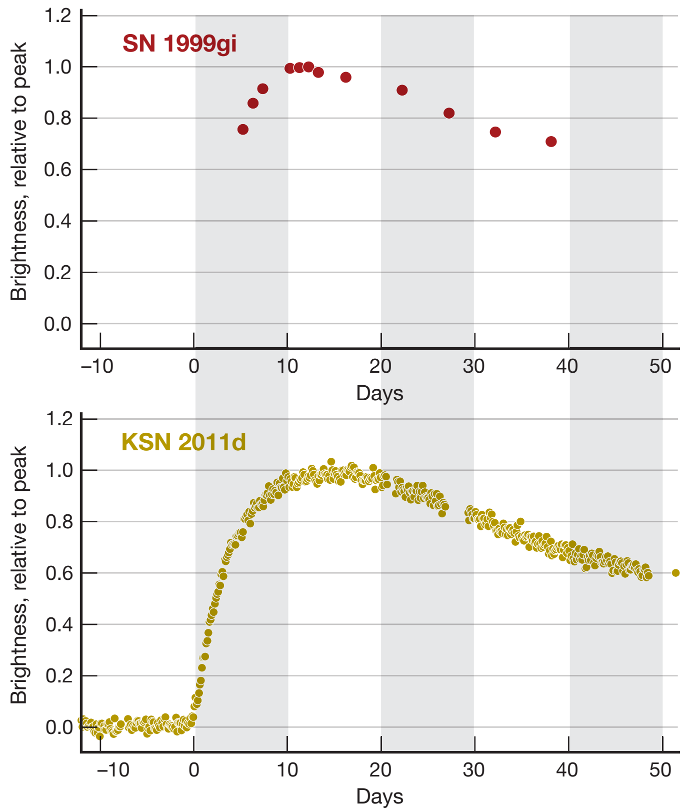
PLANETS WITH SIBLINGS IN THEIR SYSTEM
1,193

PLANETS THAT ORBIT RED DWARFS
48 About 2% of all Kepler's confirmed planets

POTENTIALLY ROCKY PLANETS
889 Radii of 1.75 Earth radii or less

These stats are taken from Kepler's primary and secondary missions. Exoplanet data are for confirmed worlds only and come from NASA's Exoplanet Archive and the Planetary Habitability Laboratory at the University of Puerto Rico, Arecibo.

TERRI DUBÉ




▲ **BEFORE & AFTER** These plots compare two light curves, one for a well-studied supernova in 1999 *(top, turquoise dots)* and the other for a supernova detected by Kepler in 2011 *(bottom)*. Each Kepler point is an average of 3 hours of data. Both supernovae were core-collapse events.

BEFORE & AFTER: LEAH TISCIONE / *S&T*; SOURCE: PETER GARNAVICH

provide the elements crucial in forming life. If cores rotate slowly, then perhaps it affects how heavier elements mix into the interstellar medium.

"That's another legacy of Kepler: It left a lot of observational puzzles that will keep the theorists busy for quite some time to come," Huber says.

## The Moment Before a Star Explodes

Although Kepler stared at some 150,000 stars in nearby reaches of the Milky Way, distant galaxies also lurked in the telescope's view. And that allowed the telescope to catch the rise of light emitted during the early death throes of a distant star.

"It was just stunning to me," says Peter Garnavich (University of Notre Dame), who has been working with supernovae for decades. Typically, astronomers catch a supernova several days or weeks after it explodes. Then they observe it every night for months. As such, a typical light curve misses the initial rise of the explosion and then includes data points taken every 24 hours.

But Kepler took the game to a new level. "It was like a theorist gave us the light curve," Garnavich says. "We had the observations before the explosions. We had it rising up every 30 minutes we had an observation. It was just unbelievably beautiful."

And such beautiful light curves have helped astronomers distinguish between competing explosion scenarios for Type Ia supernovae. All scenarios require two culprits: a white dwarf — the Earth-sized remnants of Sun-like stars — and a companion star. It's the companion star that's the mystery.

If the companion star is rather large, say a Sun-like star or a red giant, then the white dwarf takes on material from that star until the dwarf reaches the so-called Chandrasekhar limit. The increasing pressure ignites a runaway thermonuclear explosion. But if the companion star is another white dwarf, the two explode only when they collide. In theory, the two scenarios are distinguishable if astronomers can glimpse the early light from the explosion — something that was impossible before Kepler.

In the first scenario, the expanding shell of material from the white dwarf rams into the companion star, generating extra heat and light that would show up as a slight bump in the first days of a supernova's brightening. In the second scenario, there is no bump. As of today, Garnavich and his colleagues have spotted roughly a dozen Type Ia supernovae with Kepler and they haven't seen a single bump, suggesting that all companion objects are reasonably tiny.

But that doesn't mean the case is closed. On March 10, 2017, a supernova appeared in the outskirts of the spiral galaxy NGC 5643, roughly 55 million light-years away (*S&T:* July 2017, p. 11). It looked like a typical Type Ia supernova in every way except one: There was an early bump in its light curve. Models suggest that the bump occurred when the white dwarf's shock wave ran into a rather large companion star that's roughly 20 times the size of the Sun.

Garnavich hails this as the best evidence yet that a Type Ia supernova can result from a white dwarf and a larger companion star. That means the explosions can come from an array of systems — a result that has universe-scale repercussions.

> "It was just stunning to me," Garnavich says. "It was like a theorist gave us the light curve."

Astronomers use these explosions, which detonate at roughly the same luminosity, to measure distances. These cosmic mileposts have provided the best evidence yet that our universe's expansion is accelerating, caused by something we call dark energy. But astronomers haven't been able to pin down exactly what dark energy is. Garnavich thinks that with these observations, we're one step closer. It could be, he says, that understanding exactly how these supernovae explode will enable astronomers to take more precise measurements of the cosmos and pin down a model for dark energy.

## Making Lemonade

In July 2012, one of Kepler's four stabilizing reaction wheels failed, and then in May 2013 a second one broke, leaving the


▲ **CAMPAIGN FIELDS** Kepler originally stared continuously at a region of sky in Cygnus and Lyra (yellow grid field). Now confined to the ecliptic after technical mishaps, the repurposed space telescope points at a different field every 80 or so days. Shown are completed K2 campaigns (yellow outlines) and those upcoming when we went to press (orange). Campaign 16, which begins in December 2017, is dedicated to searching for supernovae.

spacecraft without the ability to point itself precisely toward a single spot in the sky. But NASA wasn't willing to give up on the scope, even if it was a little shaky.

Engineers developed an alternative plan, in which the telescope uses radiation pressure from the Sun to stay stable. But it can no longer stare at a single patch of sky as it did before. Instead, Kepler is limited to observing campaigns that each last roughly 80 days before the telescope has to reposition itself. It is also confined to observing near the ecliptic plane. Both raise a list of pros and cons for Kepler's stellar astrophysics, but Jenkins argues that the new situation is the "best worst thing that ever happened to Kepler."

For the most part Kepler has shed light on the evolution of Sun-like stars — particularly ones that are as mature as the Sun or older. But now that Kepler has the freedom to point along the ecliptic, it will have the opportunity to observe the opposite side of the spectrum: young stars. That's because regions of star formation (like those toward Taurus, Sagittarius, and Scorpius) dot the disk of our galaxy, which twice crosses the ecliptic.

"It's an amazing second act for Kepler," Kawaler says.

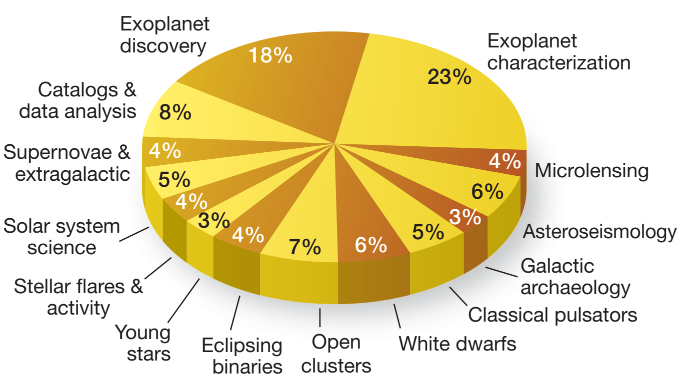
K2 may also help solve some of the mysteries Kepler created, like those surrounding supernovae. In December 2017, the telescope will start to monitor roughly 15,000 galaxies with the hope of catching somewhere between 10 and 15 supernovae. Garnavich wants to use these supernovae to determine — once and for all — what triggers them.

Not only will K2 help shed light on stellar evolution, but it will also reveal surprising details about galactic evolution. By using asteroseismology to map the masses, sizes, and ages of hundreds of thousands of stars across the Milky Way, astronomers will better understand when stars started to form and where. And that result will help them chart the development of our galaxy in unprecedented detail.

Even with K2 well under way, scientists are still mining the data from the original mission. It's the only data set that gives four continuous years of brightness measurements, which makes it "the best resource for doing this sort of science that we have at the moment," Huber says. "I believe there is still more to be found in the Kepler data."

■ While writing this story, freelance science journalist **SHANNON HALL** witnessed two awesome — and life-changing — celestial events: the total eclipse of the Sun and, later, the northern lights.

## K2 Papers, By Science Topic




GREGG DINDERMAN / *S&T*, SOURCE: KEPLER & K2 / NASA AMES RESEARCH CENTER
K2 PAPERS: LEAH TISCIONE / *S&T*; SOURCE: KEPLER & K2 / NASA AMES RESEARCH CENTER

# Hot Prod

1

## 1 STARGATE DOBS

**Sky-Watcher** skywatcherusa.com

For deep-sky observers there's nothing like a large-aperture telescope to make chasing faint fuzzies a rewarding experience. These new 18- and 20-inch f/4 Dobsonians from Sky-Watcher offer a host of standard features, such as lightweight mirrors that acclimate quickly to changing temperatures, and optional motor drives with Go To pointing, at a cost significantly lower than comparable scopes. Watch for our review of the 18-inch Go To model in the coming months.

• **U.S. price: from $5,999**

# ucts2018

*Each year, S&T editors scour the marketplace searching for what we consider to be the year's most exciting new products. To make our list, a product should introduce new (or improve upon existing) technologies, provide a solution to an old problem, or simply deliver exceptional value. Our Hot Products list for 2018 includes a variety of gadgets ranging from mounts, cameras, and accessories aimed at the growing popularity of robotic astronomy to items big and small for observers who love being out under a starry sky. As is often the case, this year some products caught our eye because of their exceptional value — equipment that offers features and performance at a cost well below that of similar items in the past. We hope you enjoy reading about these innovative products that piqued our interest.*


2

3


4

## 2 TWIST-LOCK STAR DIAGONALS

**Orion Telescopes & Binoculars** oriontelescopes.com

A quick twist of the red ring tightly locks eyepieces and camera adapters into these 90° mirror star diagonals with dielectric coatings that provide 99% reflectivity. Models are available in 1¼- and 2-inch sizes. The nosepiece of each is threaded for filters and has machined baffles to reduce light scatter. Both are made of anodized aluminum, and the 2-inch model includes a 1¼-adapter with the same twist-lock feature.

• **U.S. price: $119.99 and $189.99, respectively**

## 3 MULTI-PURPOSE LANTERN

**Orion Telescopes & Binoculars** oriontelescopes.com

Any observer will tell you that having a good light handy when you're out stargazing is worth its weight in gold. The Orion DualBeam Astro Lantern is a waterproof, multi-purpose, LED unit built around a rechargeable 2,600 mAH lithium battery. You can cycle through four brightness levels of red light and two of white, and the light can be turned off from any setting without cycling through the others. Magnetic clips, a carabiner, and a wrist strap are included, and the little lantern packs enough juice (and USB port) to boost the battery life of most mobile devices.

• **U.S. price: $24.99**

## 4 PREMIUM 6-INCH REFRACTOR

**Stellarvue** stellarvue.com

If you're in the market for an American-made, premium APO refractor, the competition is pretty thin for apertures greater than about 5 inches. The new Stellarvue SV152T stands out as the only scope offering at least 6 inches of aperture for less than $10 grand (and thousands of dollars less than the nearest competitor). The scope's 3-element f/8 objective is made with ED glass, and an optional field flattener is available as well as an optional focal reducer. Standard features include a 3.5-inch Feather Touch focuser, machined tube rings, Losmandy-style dovetail bar, and rugged transport case.

• **U.S. price: $8,995**

## 5 IMPROVED SOLAR VIEWING
**Meade** meade.com

Four new SolarMax III telescopes are the latest generation of Meade's Coronado line of dedicated hydrogen-alpha solar scopes. Each comprises a 70-mm f/5 refractor with a 2-inch dual-speed rack-and-pinion focuser and a 90° diagonal with a built-in blocking filter. The models with a 0.7-angstrom bandpass have a single tunable 60-mm hydrogen-alpha filter mounted in front of the objective, while the 0.5-angstrom models have a double-stacked filter set. Remove the objective filter and substitute a standard diagonal, and you have a 70-mm scope for nighttime observing.

• **U.S. price: from $2,299**


## 6 STAR ADVENTURER MINI
**Sky-Watcher** skywatcherusa.com

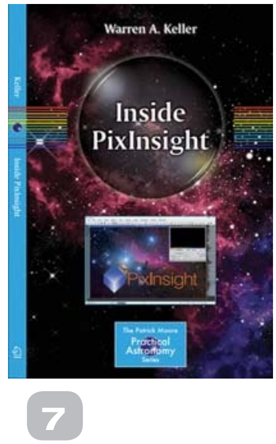
The Star Adventurer Mini, or SAM for short, stands out from the increasingly crowded market of small camera trackers made for astronomy by adding a slew of new capabilities to a very modestly priced model. Among them are the ability to track the sky for long exposures as well as offer motion control and panning for time-lapse sequences. You can get all the details in Alan Dyer's in-depth product review in the December 2017 issue, page 58.

• **U.S. price: $299**


## 7 PIXINSIGHT GUIDE
**Springer International Publishing** springer.com

Those awe-inspiring astrophotos splashed across magazine pages and the Internet owe much of their beauty to advanced image-processing techniques. Warren Keller's guide to *PixInsight* — one of today's most popular astronomical image-processing programs — provides detailed information on how to transform the raw data from your camera into gallery-worthy images. There's a good reason this book has become a best-seller in its category.

• **U.S. price: $34.99 (softcover), $24.99 (ebook)**




## 8 OPEN-SOURCE GO TO CONTROLLER
**Explore Scientific** explorestars.com

Go To pointing has become virtually standard fare on any motorized telescope. But what makes the PMC-Eight System for select Explore Scientific and Losmandy equatorial mounts special is its ease of adapting to other mounts and, most notably, its open-source architecture complete with a programmer's reference and software-development kit. This, according to the company, allows programmers to create custom Go To software to suit the needs of observers and researchers. Not a programmer? Don't worry, the system and its free app currently offer wireless control of mounts with Windows computers and mobile devices.

• **U.S. price: $1,499**


## 9 S&T'S CELESTIAL GLOBES
**Sky & Telescope** shopatsky.com

Think we'd have a year without a Hot Product pick of our own? Fear not. The popularity of our growing family of 12-

10

11


12


13

inch planet and celestial globes has spawned a series of 6-inch semi-gloss-finished orbs for Earth, Moon, Mars, and Pluto. As with their bigger counterparts, each is based on detailed spacecraft imagery and has prominent features labeled. And the Earth globe emphasizes our home world as a planet without geopolitical boundaries. Each includes a plastic stand and information card.

• **U.S. price: $24.99 each**

## 10 FINISHED CELLULAR MIRRORS
**Dream Cellular** dreamcellular.com

Dream Telescopes and its sister company Dream Cellular have been perfecting lightweight-mirror technology for more than a decade. And its cellular mirror blanks were named one of our Hot Products for 2010. Now the company is offering finished lightweight mirrors from as small as 25-mm diameter up to apertures greater than a meter. It can also fabricate custom carbon-fiber mirror mounts that thermally match the optics.

• **U.S. price: projects quoted individually**

## 11 COMPACT REFRACTOR
**Astro-Tech** astronomics.com

We know of countless life-long amateur astronomers who got started sweeping the heavens with 60-mm refractors, so there's no denying that these scopes can deliver a satisfying observing experience. And lately the market has seen an increasing number of compact APO models. But the Astro-Tech AT60ED 60-mm f/6 with its 2-inch, dual-speed focuser offers the biggest bang for the buck that we're aware of. Coupled with an optional field flattener, it doubles as a powerful, wide-field imaging scope.

• **U.S. price: $369**

## 12 PINT-SIZE PRECISION
**Starlight Instruments** starlightinstruments.com

With all of today's emphasis on 2-inch and larger focusers, it's nice to see that the legendary features, quality, and precision of Feather Touch focusers are now available with two 1¼-inch models, one offering a single-speed drive, the other 10:1 dual-speed. Both have ¾ inch of travel, an 8-pound load capacity, a travel brake, and a drawtube with male T-threads for easy attachment of cameras and accessories.

• **U.S. price: from $249**

## 13 ALTAZIMUTH PARAMOUNTS
**Software Bisque** bisque.com

Software Bisque, the world's foremost manufacturer of equatorial telescope mounts for remote/robotic astronomy, has announced its first foray into building altazimuth mounts (and modifying its storied *TheSkyX* software to control them). While every mount design has pros and cons, advantages for altazimuth mounts include simplified mechanical design of telescopes and fitting large-aperture instruments into a compact area of operation (think smaller domes). The new mounts include models with traditional drive gears as well as ones with direct-drive motors.

• **U.S. price: from $30,000**

## 14 PREMIUM BINOCULARS
**Astro-Physics** astro-physics.com

There are countless binoculars on the market, but only two models carry the Astro-Physics name. According to company founder Roland Christen, these 11×70 and 16×70 binoculars offer a flatter field, are sharper at the edges, and have reduced color fringing compared with the previous versions deemed excellent enough to be in the company's product lineup. Made with individual-focus eyepieces and full-illumination BAK4 porro prisms, the 11× model has a 4.8° field of view and the 16× a 4.1° field.

• **U.S. price: $460 (11×70) and $520 (16×70)**

## 15 ONE-ARM ROBOTIC MOUNT
**PlaneWave** planewave.com

Built to operate in either altazimuth or equatorial mode, PlaneWave's new L-500 Direct Drive Mount is rated for telescope loads up to 200 pounds. The single-arm design has dovetail connections on both axes, making it extremely easy to balance loads regardless of their size and shape. High-resolution encoders on both axes provide precise pointing with slewing speeds up to 50° per second. Optional hardware allows mounting telescopes on both sides of the fork arm simultaneously.

• **U.S. price: $18,000**

## 16 DIGITAL DETECTOR
**Sony Semiconductor** sony-semicon.co.jp

In 2015 Nikon grabbed the attention of astrophotographers with the introduction of its 36-megapixel, astronomy-friendly D810A DSLR (reviewed by Jerry Lodriguss in the February 2016 issue, page 56). The full-frame, color CMOS detector at the heart of that camera — Sony's IMX-094AQP — is now working its way into cooled astronomical cameras made by ZWO and QHY. This is good news for those wanting the features and improved imaging performance offered by a cooled astronomical camera. Will other camera manufacturers follow? Time will tell.

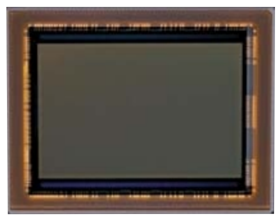
• **U.S. price: camera from $3,999**

## 17 MOBILE IMAGING
**ZWO** astronomy-imaging-camera.com

Digital astronomy is increasingly mobile these days with apps taking on the tasks that were once possible only with desktop and laptop computers. ZWO's free *ASIcap* app for Android devices (running OS 4.4 and up) has achieved a mobile milestone by offering total operation of ZWO ASI USB 3.0 cameras with just the mobile device (some devices require an external power source). It's no longer necessary to cart along a computer to take and store images and videos with these cameras, thus lightening the load for astroimagers.

• **U.S. price: free**




16


DANIEL KRASON / BIGSTOCKPHOTOS.COM


18


19


20

21


## 18 ALUMA SERIES COOLED CAMERAS
**SBIG** diffractionlimited.com

SBIG, one of the most trusted names in cooled astronomical cameras, started with a clean piece of paper when creating its Aluma Series cameras for medium-sized detectors, including Sony's ICX-694 and ICX-814 CCDs and Kodak's KAF-8300 CCD. All models have dual-stage thermoelectric cooling down to 50°C below ambient temperature and computer connectivity by USB 2.0 and WiFi, with the latter offering direct control with tablets and smartphones as well as conventional Windows, Macintosh, and Linux computers.

• **U.S. price: from $3,699**

## 19 NIGHT-VISION SYSTEM
**TNVC and Tele Vue** tnvc.com & televue.com

Tactical Night Vision Company and Tele Vue Optics teamed up to create an unusually versatile night-vision system for astronomy. While the military-grade TNV/PVS-14 Gen3 night-vision monocular can be used as a standalone 1× viewer, a custom adapter allows it to connect to any Tele Vue eyepiece that is Dioptrx compatible, opening up a wide range of telescopic observing possibilities. And there's also an adapter for the Tele Vue FoneMate. Anyone for deep-sky astrophotography with a cellphone? Don't laugh; our upcoming review will explain how it's done.

• **U.S. price: from $3,195**

## 20 OBSERVATORY REMOTE CONTROL
**Lunático Astronomia** tienda.lunatico.es

Computer programs for running telescopes and cameras remotely have gone mainstream in recent years, but most don't address the issue of turning power on and off for equipment. Lunático's Dragonfly Observatory Controller is an Internet-connected device that can manage the power for up to eight devices, as well as monitor such things as weather conditions and observatory roof position all via an app available for Apple and Android mobile devices.

• **Price: 450€ (about $530)**

## 21 70-MM ASTROGRAPH
**Meade** meade.com

Wide-field astrophotography has become extremely popular in recent years, especially for people shooting with DSLR cameras. And for many this new 70-mm f/5 astrograph incorporating ED-glass lenses in a 4-element Petzval design is an ideal instrument. Its 42-mm imaging circle will cover a full-frame DSLR with a field of view more than 5¾° wide. It comes standard with a 2.5-inch 10:1 dual-speed focuser, tube rings, and a Vixen-style dovetail bar.

• **U.S. price: $1,199**

# Making Your Nightscapes "Pop"

Use these easy steps to turn your landscape astrophotos into personal masterpieces.

Photography of landscapes under a starry sky is a unique art form that until recently, only a handful of imagers were doing. I remember going to the most popular spots within California's Yosemite National Park at night, where I'd rarely encounter anyone with a camera and a tripod in the wee hours. Fast-forward to today, and this type of adventure photography has entered the mainstream commonly featured in television and print advertisements hawking everything from smartphones to SUVs.

The most amazing nightscapes are often a combination of careful planning and inspired work, with a hefty dose of luck. Still, many published nightscape images could be improved with additional attention during post-processing. It only takes a few steps to take a nightscape image from looking dull to dazzling, and these steps don't require much skill or computer wizardry.

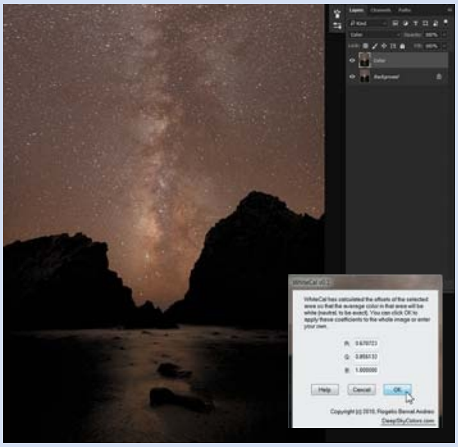
The main tasks that can turn a nightscape image beautiful quickly are color balance and selective processing. In many nightscapes, it's crucial that the sky and the landscape are treated differently.

## Setting the Color Balance

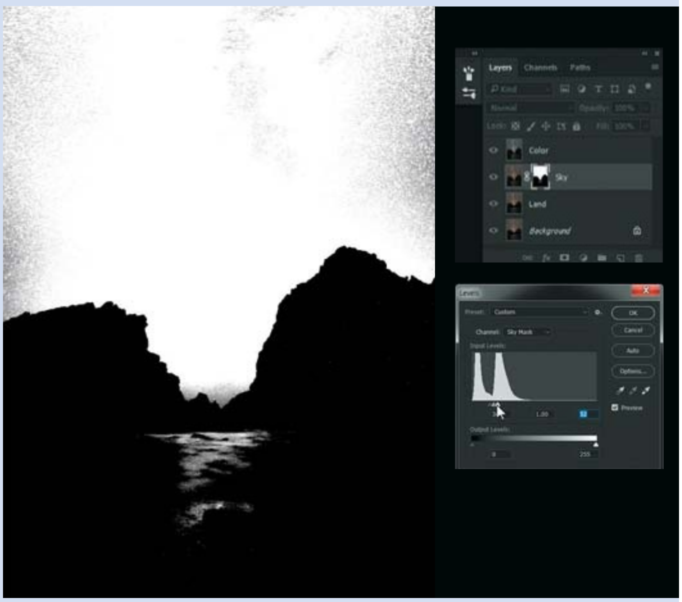
The first step to improving your nightscape photos is to establish a proper color balance. Many photographers use a custom color correction that is applied in-camera to their photos. I prefer not to use this, as I find it less reliable than the choices I can make during post-processing. Additionally, the in-camera values need adjustments within a single night

◀ **ARTISTIC ENHANCEMENT** Nightscape photography is more than just snapping photos of the stars over a pretty landscape. The results, like the shot at left, require additional post-processing to reach their full potential as seen on the facing page. In this article, Rogelio Bernal Andreo shares some easy techniques to make your own images stand out from the crowd. All images are courtesy of the author.

◀ **WORKING IN LAYERS** Every adjustment to an image should be done on a new layer, in order to preserve the original image; changes can be undone if necessary. A copy of the original photo is created, then this layer can be used to adjust particular aspects of the original, such as color or contrast.



◀ **COLOR BALANCE** Most night-sky images coming out of your camera will have a reddish-brown cast. This is often easiest to correct on the Color layer using the Auto Color command, or using the author's free plug-in filter *WhiteCal* (shown at left).




▲ **LAYER MASKING** A critical step in nightscape processing is to address the sky and the landscape separately through layer masks. Two copies of the background layer are created (called Land and Sky) below the color layer, and a layer mask is then added to the latter. Paste another copy of the original image into the layer mask, which can then be adjusted using the Levels tool to make a high-contrast mask.

as the conditions change. I set my camera color profile to daylight, so all my RAW images often feature a warm, brown color cast that I then correct on the computer. There are two quick ways to perform an easy but often effective color balance. Note that while I describe these steps while using *Photoshop CC*, users can use similar approaches with other image-processing software.

Since I'm working with color information, I begin by opening the layers window in *Photoshop* and creating a duplicate layer from my original image. I then change the layer blending mode of this new layer to Color, and retitle the layer from the default title "layer 1" to "color." I then select this new layer and apply the Auto Color function from *Photoshop*'s pull-down menu (Image > Auto Color). This sometimes produces a good result. If the colors appear a bit washed out, I can bring them back by increasing the color saturation (Image > Adjust > Hue/Saturation).

If Auto Color doesn't produce the desired outcome, a second approach is to try the plug-in filter *WhiteCal* that I wrote several years ago (**https://is.gd/QcKYT0**). The plug-in works by adding it to the filters folder in *Photoshop*, then selecting a spot in the image that you consider to be a good white reference using the Lasso or Magic Wand tool. Select something that should be a neutral color, then run the filter using Filter > DeepSkyColors > WhiteCal. The plug-in will then adjust the colors on the entire image so that the average color of your selection is neutral.

But either approach can sometimes fail. When using *WhiteCal*, I tend to experiment with different white reference selections until I'm pleased with the result. If there's nothing in the image that I can use as a white reference, I'll try selecting a small area of the sky background, preferably near the top where the sky color tends to be more neutral.

Which of these tools give the best results for any given image is something you'll need to experiment with every time they're used. More often than not, the color of your image should improve with just a couple of clicks. Once you're satisfied with the color balance, bring up the Hue/Saturation tool to intensify the color. Moving the saturation slider to somewhere between 10 and 30 usually works well.

## Selective Processing

At this point you should have two layers: the original image (called *background* in the Layer window) and a color layer. It's time to create two new layers, both also duplicating the original layer by clicking on the background layers and selecting Layer > Duplicate Layer from the pull-down menu. Rename these new layers "Land" and "Sky." The layer list should then appear as follows, from bottom to top: Background, Land, Sky, and Color.

These layers are necessary because nightscapes recorded when the Moon isn't up tend to have a nice, bright sky but dark land features, appearing almost like a silhouette. You might not have this problem if there was some light illuminating the foreground — street or car lights, or your own flashlight "painting" in the landscape — but either way, being able to separately process land and sky gives you the most control over the final result. I use layer masks to do this selective processing in *Photoshop*.

I only need one mask to separate the land and sky in my nightscape, which I'll create on the Sky layer. To do this, I select the Sky layer, and create a layer mask from the pull-down menu (Layer > Layer Mask > Reveal All). I then copy the original image by clicking on the background layer and using Select All and Edit > Copy. Next, I hold the Alt key and select the layer mask, then paste this image into it by selecting Edit > Paste. Now, with the mask on the sky layer selected and visible, I'll open the Levels tool to start clipping both the shadows and highlights (Image > Adjustments > Levels), always paying attention to the boundary where the land and sky meet. These adjustments can be made to the entire mask, or just in small troubling areas, via a quick selection with the Lasso or Magic Wand tool. Eventually I find a good compromise across the entire area where land and sky meet.

If the transition between black and white in the mask is too harsh, a slight application of a blur filter (Filter > Blur > Gaussian blur) or a small maximum/minimum transformation (Filter > Other > Maximum/Minimum, Preserve Roundness) helps to soften the transition.

Sometimes small adjustments might need to be done manually with the Brush tool on the mask layer. Brush size and hardness play an important role anytime we use them in a mask, but trying to detail even a handful of situations would be daunting. The most important thing to keep in mind when using the brush to refine your mask is that you want a soft brush — 0% or similar hardness — when a smooth transition is desired, while a brush with its hardness set between 35% and 85% is best for more detailed, sharper transitions.

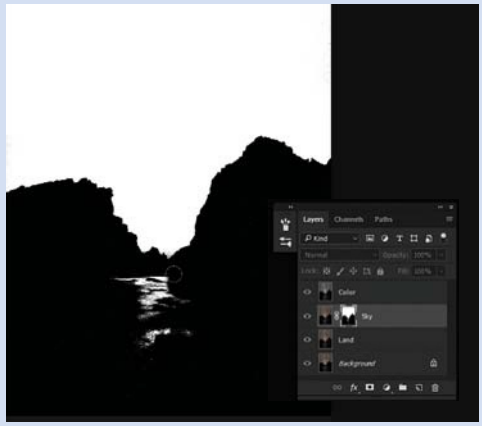
Creating good masks might take a bit of time to master, but it's just a matter of practice. The good news is that if you're already experienced with deep-sky image processing, the challenges that require masks in nightscapes are much easier to solve than the many situations with telescopic images where very elaborate masks are often required.

## Contrast and Brightness

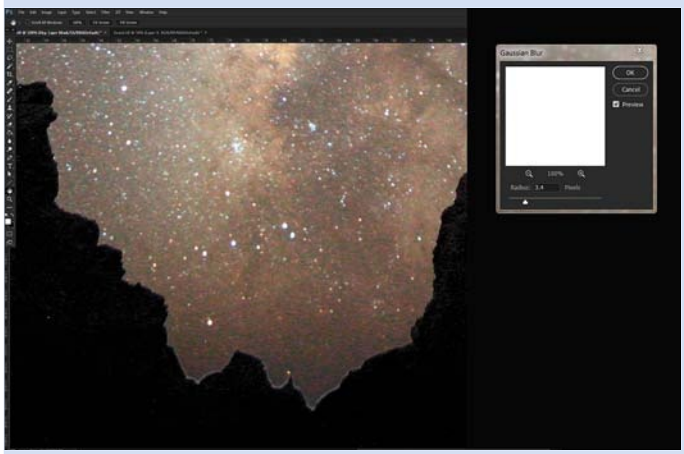
Now let's concentrate on the Sky layer. I prefer to clean up the hazy appearance that nightscapes often display by using the new Brightness/Contrast tool in *Photoshop CC*, located at Image > Adjustments > Brightness/Contrast. While this tool has some detractors, if not abused, it often works effectively. You can find whether your copy of *Photoshop* uses the new version of this tool because it offers a "Use Legacy" option for the older version.

The adjustments that I've found to be most effective for the sky involve increasing the contrast by a fair amount, then increasing the brightness amount to taste, but not much. For the land, usually a decent increase in brightness and a tad of contrast works well. Always try to keep an eye on the results to avoid overdoing it. Selective processing can make a good

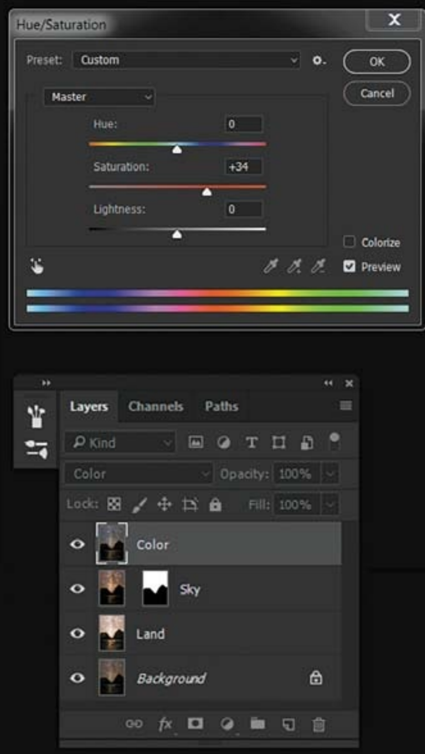
▶ **REFINING THE MASK** Make additional edits to the layer mask, such as removing any white areas you don't want to be affected, by painting out the areas with the Brush tool.



▲ **TWEAKING THE SKY** With the layer mask in place, any adjustments to the Sky layer will only affect the sky, without changing the landscape. Edits to the foreground can be performed on the Land layer.



▲ **MASK REFINEMENT** The point where the land and sky meet will become more obvious as you work on the individual Sky and Land layers. This can be fixed by applying a blur filter to the mask to make its transition appear more natural.




**FINAL ADJUSTMENTS** When you're satisfied with the overall balance between the land and sky in your nightscape, you may want to increase the saturation of the top Color layer.

image look artificial or like a composite of multiple images very quickly. If the image starts to look like a composite of two separate shots, then I've gone too far and should back off. I tend to keep the History window open in case I need to go back several steps and try again.

As I adjust either the Land or the Sky layers, the quality of the transition in the mask I created earlier will become more obvious, and I might feel the need to go back to the mask and refine it a bit more. Additionally, every brightness adjustment usually reduces the color saturation — the brighter the image, the more washed out the colors appear — and I often find myself readjusting color saturation on the Color layer. If you're aiming at producing a nightscape that doesn't feel "overcooked," avoid increasing the contrast very much and definitely go easy when raising the color saturation.

Playing effectively with these three elements of your image — brightness/contrast of land and sky, color saturation, and refining your mask until you find the appropriate balance in the image — is something that might take a few tries at first, but it eventually becomes second nature. The beauty of this process versus using tools such as *Adobe Camera RAW*'s "Dehaze" filter is that you're in control of each element, which should help you craft your image without limiting yourself to what a single tool could do.

Once you're satisfied, you can consider the image finished or choose to work more on it. If the latter, the good news is that now you have a much improved image to work with. It also means you can move onto learning more elaborate techniques for nightscape image-processing beyond these necessary steps.

This simple conceptual workflow works for me, but subtlety is in the details. Nightscapes are intrinsically artistic images, and as in any other form of art, the tools and techniques are only there for you to use them on your own terms, not to guide you.

■ ROGELIO BERNAL ANDREO hosts astrophotography workshops throughout the United States and Europe. For more information, see his website at deepskycolors.com.

# OBSERVING
## January 2018

**1** **MORNING:** The New Year kicks off with Mercury at greatest western elongation. Look toward the southeast before sunrise and you might catch a glimpse of this tiny world.

**EVENING:** The first full Moon of the year (for viewers in North America) coincides with its closest perigee of the year.

**3–4** **NIGHT:** The short-lived Quadrantid meteors peak for North America, but the full Moon makes viewing any of this shower's meteors a challenge.

**4–5** **NIGHT:** The Moon slides past Regulus in Leo and will occult the 1st-magnitude star for viewers in parts of northern Canada and Alaska.

**6** **DAWN:** Find Libra, and you will see Mars and Jupiter shining less than ⅓° from each other. Alpha (α) Librae sparkles 2° to the upper right of the pair.

**11** **DAWN:** Jupiter and Mars are joined by the waning crescent Moon. Look about 20° lower left of the trio to find Antares.

**12** **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 9:45 p.m. EST (6:45 p.m. PST); see page 50.

**13** **DAWN:** Tiny yet shiny Mercury is joined by majestic Saturn as they rise less than ½° apart in the southeast just before sunrise. The Moon hangs some 6° upper right of Saturn.

**15** **DAWN:** The thinnest sliver of a waning crescent Moon, having just been at its most distant apogee for the year during the night, joins Mercury and Saturn to form a delightful compact triangle.

**27** **MORNING:** As the Moon returns to full, it occults Aldebaran in northwestern North America; see p. 50.

**31** **ALL NIGHT:** The asteroid Ceres arrives at opposition and is expected to shine at magnitude 6.9. Bring binos to spot this dwarf planet.

**MORNING:** The last day of January heralds the second full Moon of the month. Much of western North America will witness the first total lunar eclipse in over 2 years (see p. 48).

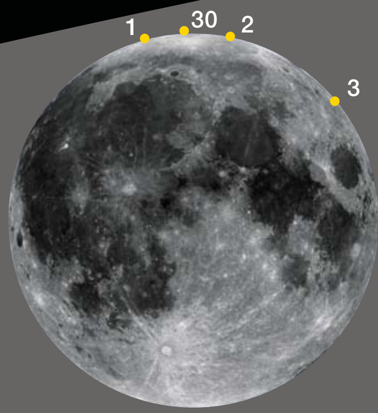
▲ NASA's MESSENGER spacecraft arrived at Mercury in 2011 and proceeded to study the tiny planet using multiple scientific instruments.

NASA / JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY / CARNEGIE INSTITUTION OF WASHINGTON

**JANUARY 2018 OBSERVING**

**Lunar Almanac**

**Northern Hemisphere Sky Chart**




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

NASA / LRO

## MOON PHASES

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

**FULL MOON**
January 2
2:24 UT

**LAST QUARTER**
January 8
22:25 UT

**NEW MOON**
January 17
02:17 UT

**FIRST QUARTER**
January 24
22:20 UT

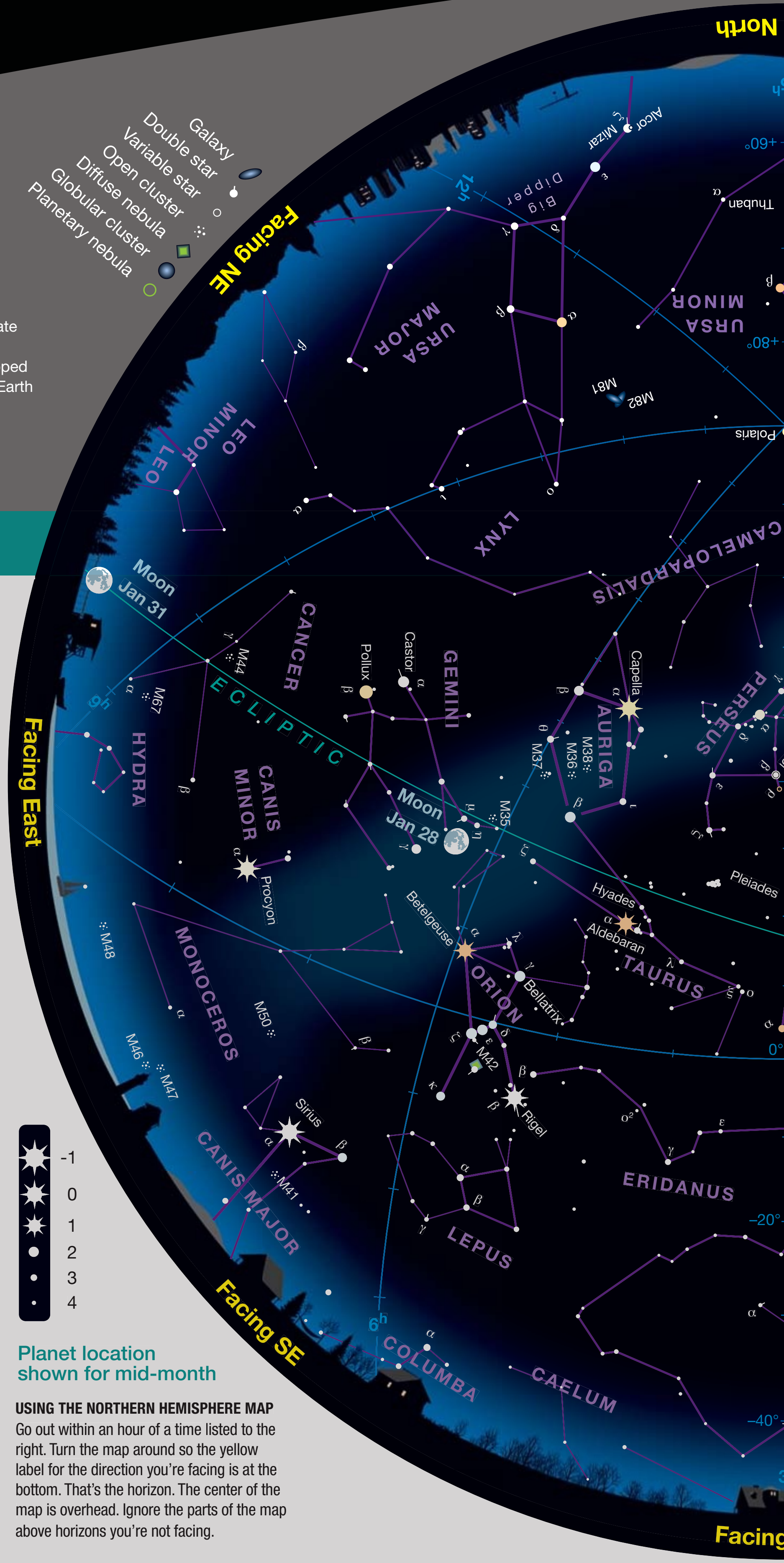
**FULL MOON**
January 31
13:27 UT

### DISTANCES

| | |
|---|---|
| Perigee<br>356,565 km | January 1, 22h UT<br>Diameter 33′ 31″ |
| Apogee<br>406,464 km | January 15, 02h UT<br>Diameter 29′ 24″ |
| Perigee<br>358,994 km | January 30, 10h UT<br>Diameter 33′ 17″ |

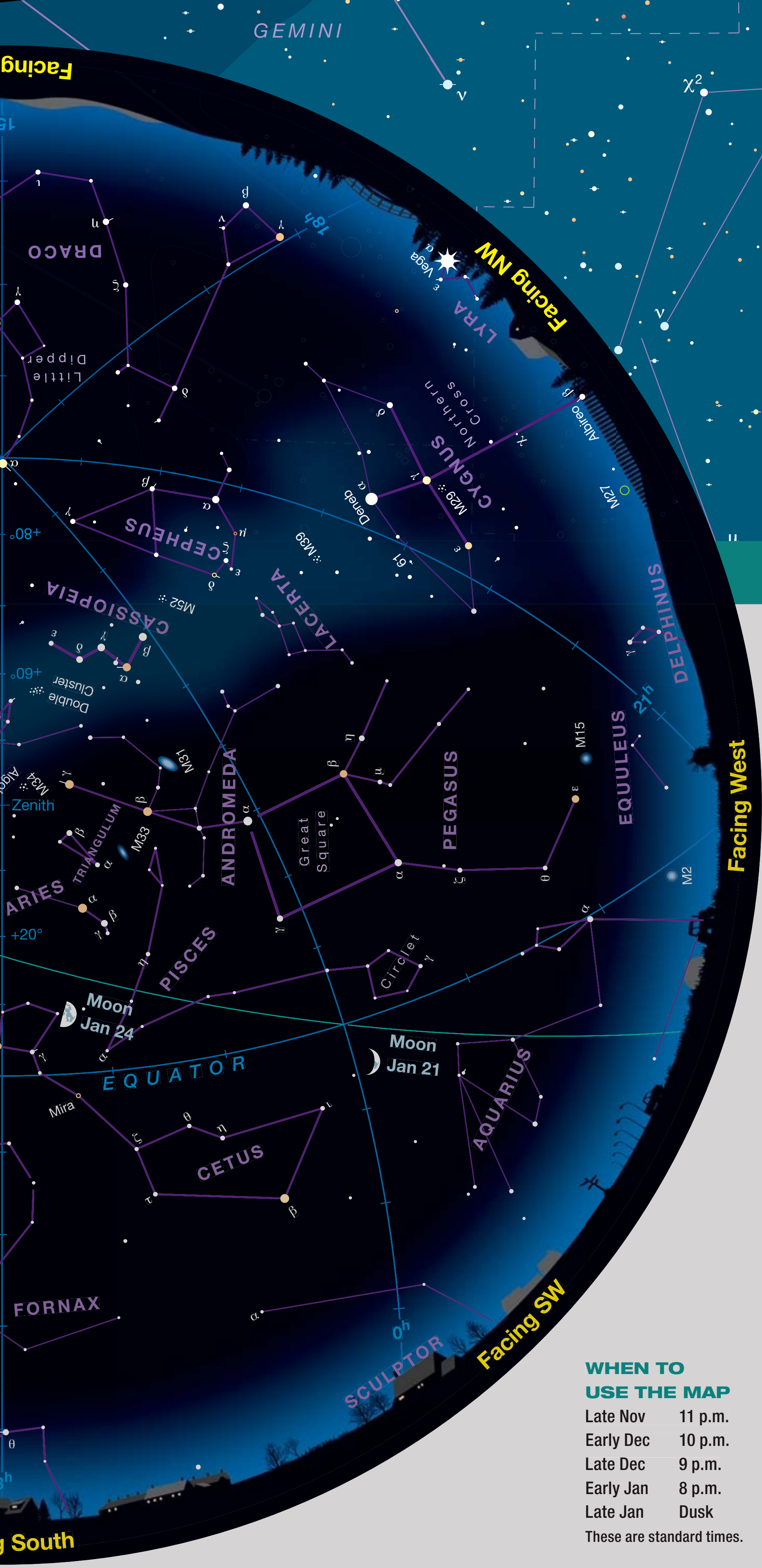
### FAVORABLE LIBRATIONS

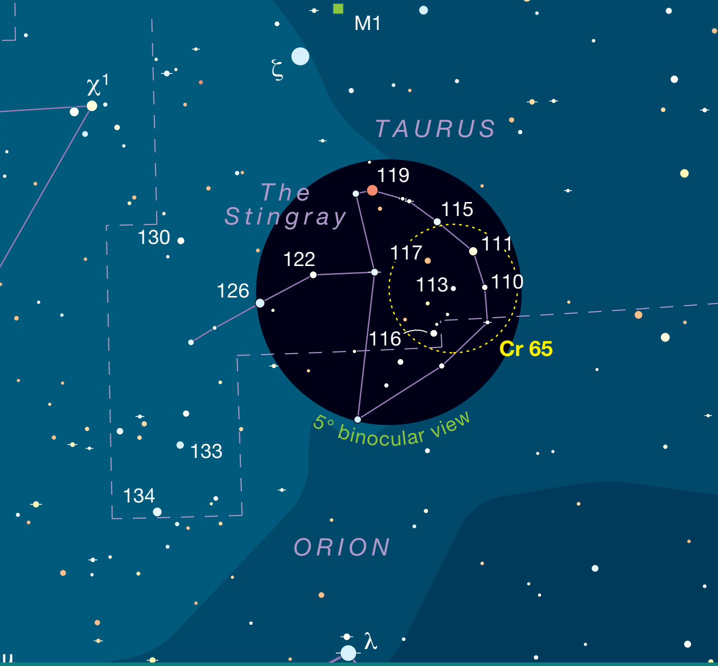
| | |
|---|---|
| • Pascal Crater | January 1 |
| • Scoresby Crater | January 2 |
| • Cusanus Crater | January 3 |
| • Gioja Crater | January 30 |




Planet location shown for mid-month

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




**WHEN TO USE THE MAP**

| | |
|---|---|
| Late Nov | 11 p.m. |
| Early Dec | 10 p.m. |
| Late Dec | 9 p.m. |
| Early Jan | 8 p.m. |
| Late Jan | Dusk |

These are standard times.

**Binocular Highlight** by Mathew Wedel

# A Stingray in the Sky

I spent a few years fanatically working my way through observing lists. But these days I'm just as likely to head out with no firm plan or destination, and see what the sky serves up. I don't see as many different things, but I discover more.

I was on a ramble through the Milky Way last winter when I stumbled on a rich concentration of stars on the boundary between Orion, the Hunter, and Taurus, the Bull. Even low-power binoculars will show about two dozen stars in a fat crescent spanning 4° from north to south. From the center of the crescent, a chain of 5th- and 6th-magnitude stars runs off to the east-southeast. I can't help but see a stingray, swimming westward above Orion's head.

It turns out that I wasn't the first to snare this leviathan in the depths of the sky. The central stars of the crescent make up the proposed open cluster **Collinder 65**. I say "proposed" because further work has cast serious doubt on the cluster's reality. With distances ranging from less than 50 light-years to over 1,000, it seems that the stars of Collinder 65 are probably just a chance alignment of unrelated suns.

I'm okay with that. Science is a process of revising our understanding of the universe in light of new information. So is observational astronomy, for each of us that goes out exploring. The subtle beauty of celestial objects often resides as much in the mind as it does in the sky. I knew the stingray wasn't real when it first swam into my field of view. But it's an enchanting sight, one that draws me farther into the depths of the galaxy.

To discover for yourself how much is up there, may I politely suggest that you grab your binoculars and, well, get lost?

■ **MATT WEDEL** is out in the dark somewhere, taking his own advice.

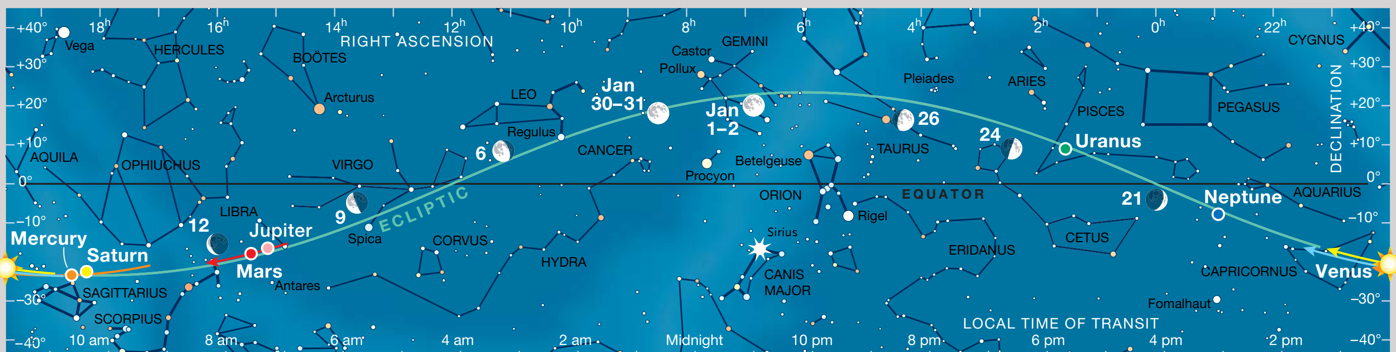

**PLANET DISKS** have south up, to match the view in many telescopes. Blue ticks indicate the pole currently tilted toward Earth.

**PLANET VISIBILITY:** **Mercury:** visible in southeast at dawn through the 19th. • **Venus:** out of sight all month. • **Mars:** visible in southeast in early morning, highest at dawn. • **Jupiter:** visible in southeast in early morning, highest at dawn. • **Saturn:** visible low in southeast at dawn after the 9th.

## January Sun & Planets

| | Date | Right Ascension | Declination | Elongation | Magnitude | Diameter | Illumination | Distance |
|---|---|---|---|---|---|---|---|---|
| Sun | 1 | $18^h\ 44.7^m$ | –23° 02′ | — | –26.8 | 32′ 32″ | — | 0.983 |
| | 31 | $20^h\ 53.0^m$ | –17° 31′ | — | –26.8 | 32′ 28″ | — | 0.985 |
| Mercury | 1 | $17^h\ 07.4^m$ | –20° 52′ | 23° Mo | –0.3 | 6.7″ | 62% | 0.999 |
| | 11 | $17^h\ 57.7^m$ | –22° 53′ | 21° Mo | –0.3 | 5.7″ | 80% | 1.179 |
| | 21 | $18^h\ 59.2^m$ | –23° 28′ | 17° Mo | –0.3 | 5.2″ | 89% | 1.303 |
| | 31 | $20^h\ 05.4^m$ | –22° 00′ | 12° Mo | –0.5 | 4.9″ | 95% | 1.378 |
| Venus | 1 | $18^h\ 36.2^m$ | –23° 39′ | 2° Mo | –4.0 | 9.8″ | 100% | 1.709 |
| | 11 | $19^h\ 30.8^m$ | –22° 38′ | 1° Ev | — | 9.7″ | 100% | 1.711 |
| | 21 | $20^h\ 24.1^m$ | –20° 28′ | 3° Ev | –4.0 | 9.8″ | 100% | 1.709 |
| | 31 | $21^h\ 15.5^m$ | –17° 19′ | 5° Ev | –3.9 | 9.8″ | 100% | 1.703 |
| Mars | 1 | $14^h\ 47.0^m$ | –15° 09′ | 56° Mo | +1.5 | 4.8″ | 93% | 1.956 |
| | 16 | $15^h\ 24.3^m$ | –17° 49′ | 62° Mo | +1.3 | 5.1″ | 92% | 1.821 |
| | 31 | $16^h\ 02.2^m$ | –20° 01′ | 68° Mo | +1.2 | 5.6″ | 91% | 1.681 |
| Jupiter | 1 | $14^h\ 58.1^m$ | –15° 49′ | 54° Mo | –1.8 | 33.1″[2] | 99% | 5.958 |
| | 31 | $15^h\ 15.1^m$ | –16° 54′ | 80° Mo | –2.0 | 35.8″ | 99% | 5.513 |
| Saturn | 1 | $18^h\ 05.0^m$ | –22° 32′ | 9° Mo | +0.5 | 15.1″ | 100% | 11.034 |
| | 31 | $18^h\ 19.4^m$ | –22° 29′ | 36° Mo | +0.6 | 15.3″ | 100% | 10.842 |
| Uranus | 16 | $1^h\ 31.2^m$ | +8° 56′ | 89° Ev | +5.8 | 3.5″ | 100% | 19.896 |
| Neptune | 16 | $22^h\ 55.1^m$ | –7° 53′ | 46° Ev | +7.9 | 2.2″ | 100% | 30.613 |

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




**The Sun and planets** are positioned for mid-January; 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.

# Across the Zenith

## Now is the time to honor your astronomical resolutions.

There are many good ways to celebrate astronomy at the start of a new year. Maybe you can watch brilliant Sirius arrive at the meridian and soar to its peak height right around the instant the new year begins. You might find (or at least observe) an asteroid on New Year's Day — as Giuseppe Piazzi did when he discovered the first (and, to this date, still the largest known) asteroid, Ceres, on not just the first day of the year but also the first day of a new century: January 1, 1801, the first year of the 19th century. New Year's Day is also a good time to celebrate astronomy by setting new goals for yourself as an observer. Perhaps your New Year's resolution will be to get a telescope with greater resolution — and use it to obtain much sharper views of all manner of celestial objects.

There are, however, two other ways of celebrating astronomy at the New Year that I'd like to discuss. The first is to take a moment and ponder the milestones in your career as an observer. The second is to spend your evenings with three bright constellations as they follow one another in a heavenly march across the zenith.

**The New Year and your personal astronomical milestones.** At some time in our life, many of us may have received our first telescope as a Christmas present, one that we could start making serious use of by the beginning of the New Year.

My own first quality telescope was the one I got for Christmas 1967, some fifty years ago. I received it not long after my 13th birthday. It was an Edmund 4¼-inch Newtonian reflector, a popular model for many of us starting in astronomy in those days. In fact, it was several decades later that I made the acquaintance of a new local observing friend who had received his own Edmund 4¼-inch only about one month before I did. He told me he'd used it straightaway to observe an occultation of the ringed planet Saturn by the Moon. I remember looking at the Moon that night with my unaided eyes and wistfully imagining what it would be like to follow the planet, globe and rings, right up to the Moon's edge. At least in the decades since, I've witnessed one delightful daytime occultation of Saturn by the Moon using a large telescope, and one absolutely astonishing grazing occultation of the majestic planet by the Moon at night.

BOB KING

Bright Sirius shines high in the wintertime sky.

**Winter's three bright zenithal figures marching in a row.** My attention on January evenings is so very often drawn to the roughly straight line that connects the Pleiades, Aldebaran and the Hyades, Orion's Belt, and peerless Sirius. But on these cold winter evenings when I turn my gaze higher, I, like other observers at mid-northern latitudes, behold a parade of three magnificent constellations, marching in a row across the zenith.

Perseus, Auriga, and Gemini proudly show off their splendors at this time of year. All three represent humans, all three are famed in myth, and all three have conspicuous patterns. Auriga boasts zero-magnitude Capella, and Gemini features 1st-magnitude Pollux. But these three constellations are also rich in 2nd-magnitude stars (six of them if you include Beta (β) Tauri that completes the pentagon pattern of Auriga) and bristling with bright open clusters: the Perseus Double Cluster; the Alpha Persei Cluster; M34 in Perseus; M36, M37, and M38 in Auriga; and M35 in Gemini.

One of the 2nd-magnitude stars is magnitude-1.9 Beta (β) Aurigae (Menkalinan), whose current RA happens to be $6^h\ 00^m$. Only two other stars in the list of the 200 brightest are so precisely on an hour line of right ascension. Remarkably, one of the other two stars is magnitude-2.6 Theta (θ) Aurigae, which shares the same line of RA with Menkalinan. By the way, of all stars north of –42° declination, Theta Aurigae appears to be the brightest without a proper name.

■ **FRED SCHAAF**, at nightfall on that Christmas 50 years ago, turned his telescope first on Capella.

# Planetary Pairings

Be prepared to get up early this month to see the dance of the planets.

The first month of 2018 offers us no bright planets until well after midnight — and normally brilliant Venus is completely lost in solar glare on the far side of the Sun. On the other hand, the final hours of the nights and the cold dawns are very exciting this January. These chilly hours offer us two very close and long-lasting conjunctions of planets (Jupiter-Mars and Mercury-Saturn); the second half of a fine Mercury apparition; and, at month's end, a total eclipse of the Moon for observers across much of North America.

## EVENING

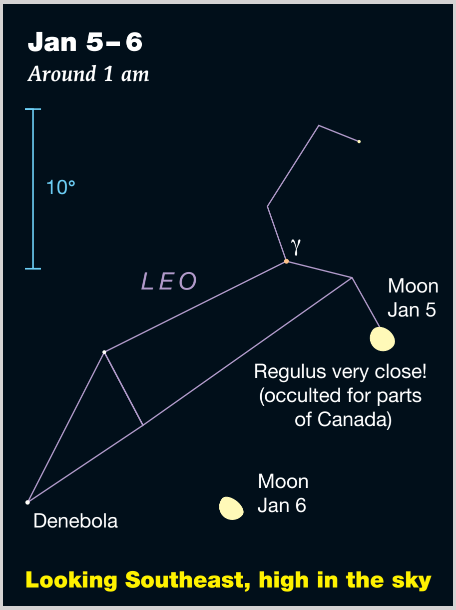
The only planets visible in the evening sky all month are dim **Uranus** and even dimmer **Neptune**. Look toward the south-southwest after the end of evening twilight to best observe them. See **https://is.gd/urnep/** for finder charts for Uranus and Neptune.

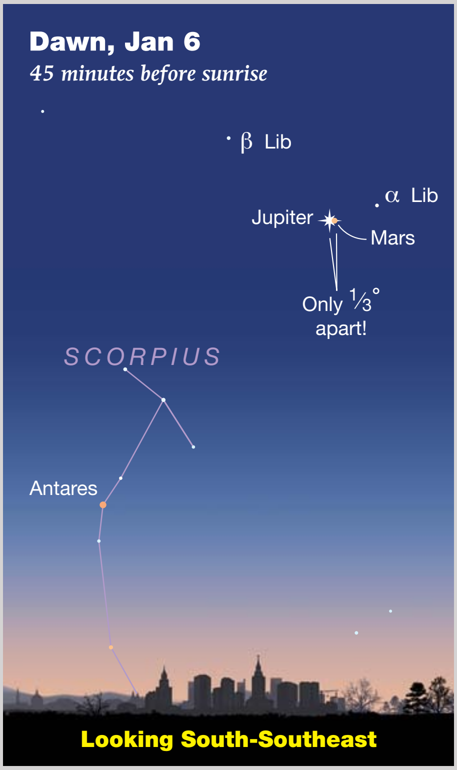
## ALL NIGHT LONG

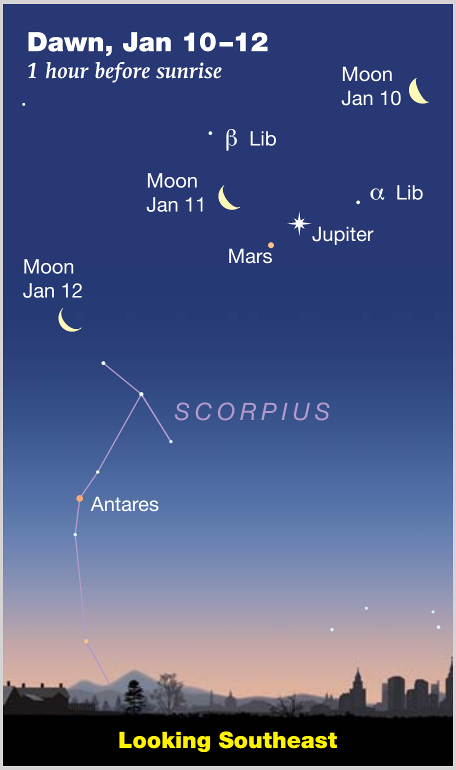
**Asteroid 1 Ceres** arrives at opposition on January 31st — in fact, within the same hour as the total lunar eclipse, when it will shine brighter than it has in over five years. Keep an eye on Vesta and Juno during 2018, for they will undergo even more rare peaks in brightness as they reach opposition in June and November, respectively.

## PRE-DAWN

January kicks off with **Jupiter** and **Mars**, initially only just over 2° apart, rising together around 3 a.m. to brighten the heavens. As the month progresses, Jupiter's magnitude increases from –1.8 to a very respectable –2.0, greatly outshining Mars, which brightens from 1.5 to 1.2 during that same period. For observers around latitude 40° north, the pair are more than 30° high in the south-southeast by 45 minutes before sunrise. That may be just high enough to get crisp images of the planets' globes in telescopes, but whereas Jupiter is 33″ wide in early January and fattens to 36″ by the end of the month, Mars is only about 5″ across. These two planets will be less than 1° apart from January 5th to 8th and make for a fascinating contrasting pair in a telescopic field of view. This is especially true at dawn on January 6th in the Americas when only ⅓° separates Jupiter from Mars!



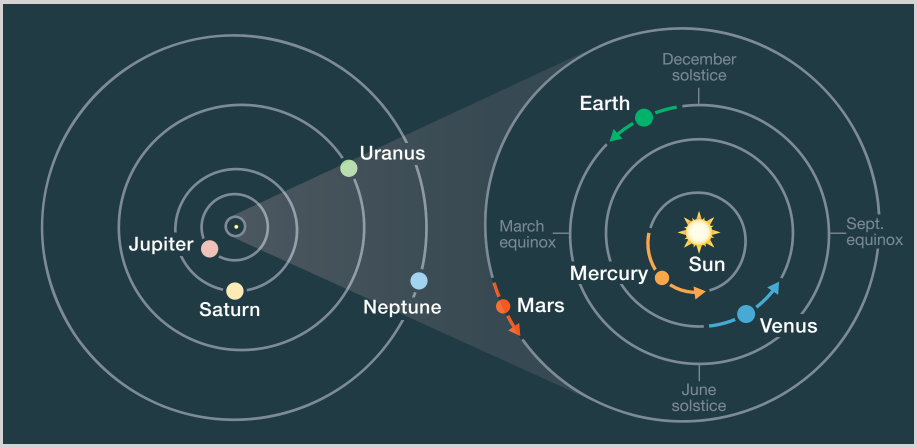



● To find out what's visible in the sky from your location, go to skypub.com/almanac.

On the morning of January 6th, Jupiter is resplendent with Mars immediately to the right and the 2.6-magnitude wide double star Alpha (α) Librae (Zubenelgenubi) some 2° to the planets' upper right. Mars-colored Antares flickers marginally into view early during twilight in the southeast, more than 20° to the lower left of the Jupiter and Mars pair. As the month progresses the two planets move away from Alpha Librae, and Mars retreats from Jupiter while advancing upon climbing Antares. Mars passes north of Antares February 6th–10th, and in July it will reach its best opposition since 2003, shining at magnitude –2.8 and looming about 5 times wider than at present in telescopes.

By the end of January, Jupiter rises as early as 1:30 a.m. local time, Mars at about 2:30 a.m., and both reach the meridian in morning twilight.

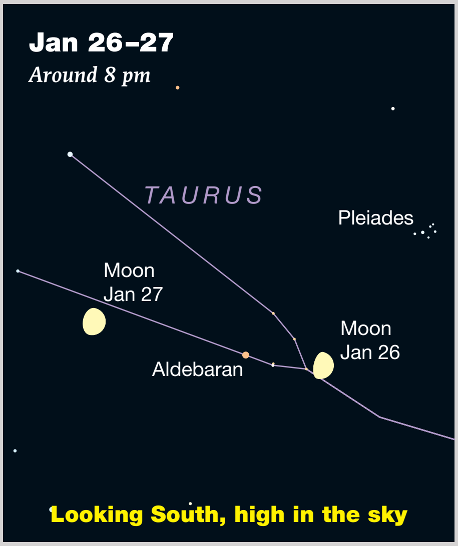



**ORBITS OF THE PLANETS**
The curved arrows show each planet's movement during January. The outer planets don't change position enough in a month to notice at this scale.

## DAWN

**Mercury** and **Saturn** form the second planetary pair in the first half of January, but much lower on the eastern horizon. Mercury shines at magnitude –0.3 as it reaches greatest elongation of 23° west from the Sun on New Year's Day, and we'll be able to witness this fine apparition for a few more weeks before the planet appears too low in the morning twilight. In contrast, magnitude-0.5 Saturn remains elusive during the year's first week but climbs progressively higher throughout the month.

On January 13th, at their closest, Mercury and Saturn shine only 0.6° apart. Mercury's gibbous globe is then little more than 5″ across, not much more than ⅓ the apparent diameter of Saturn's globe, but it will exhibit much greater surface brightness. Don't expect a very sharp view of either planet, however, for the two are still low in the southeast even 30 minutes before sunrise. In fact, it may be a challenge spotting Saturn with the naked eye at any point that morning. The situation will be quite different by month's end when Saturn rises well over 2 hours before the Sun.


## EARTH AND MOON

**Earth** reaches perihelion, its closest approach to the Sun in its orbital path through space, at 5:35 UT on January 3rd, when it is 98.3% of its average distance from the Sun.

The **Moon** is full (for the first time this month) on the North American evening of January 1st — and will appear slightly larger than usual because it will be only about 4 hours past perigee (when it's at its nearest point in its orbit around the Earth). The Moon then brushes past Regulus in Leo on the left in the middle of the night of January 4–5 (an occultation will be visible throughout parts of northern Canada and Alaska).

The waning crescent Moon forms a beautifully compact triangle with the gas giant Jupiter and rocky Mars before dawn on January 11th. Very low in the southeast, a much thinner lunar sliver is just over 6° above Saturn on January 14th and some 4° left of Mercury on January 15th. On January 31st the Moon is full for a second time in the calendar month for observers in North America, and all but the eastern part of the continent can witness that Moon totally eclipsed (see p. 48 for more details of this event).

■ **FRED SCHAAF** founded "Dark Skies for Comet Halley" and wrote the bill proposing the New Jersey Light Pollution Study Commission, both in the 1980s.

# January's Total Lunar Eclipse

The Western United States, including Alaska and Hawai'i, has the best view.

SEAN WALKER

This sequence taken during the last total lunar eclipse on September 28, 2015, was captured in seven separate exposures with a Canon Rebel XSi DSLR and an 8-inch f/3.3 Newtonian reflector.

**MORE ECLIPSE PHOTOS**
Visit our online gallery to see more spectacular images of lunar eclipses: https://is.gd/STLunar.

On Wednesday, January 31, 2018, the first total lunar eclipse in more than two years graces the skies above North America. But unlike the previous one, this eclipse is positioned perfectly for the West Coast and Pacific Rim, while the East Coast and the Atlantic Regions will see little, if any, of the show.

The eclipse occurs in the morning for western North America and the near Pacific. For the East Coast, the Moon sets before totality arrives, so the best you'll see from, say, Pittsburgh, is a partial eclipse. Viewers in the western contiguous United States (roughly west of a line drawn from Grand Forks, North Dakota, to El Paso, Texas) will have good views of most of the action, with the Moon setting at the end of or soon after totality. The farther west/northwest the viewer, the better the event. Los Angeles sees the end of totality in a brightening sky; the Moon sets before the second partial stage is complete. More northwesterly Seattle sees almost the entire eclipse, missing only the subtle end stage. Honolulu and Anchorage see every stage in an enjoyably dark sky. Alaska, Yukon, most of British Columbia, the Northwest Territories, parts of Nunavut, and Hawai'i see the eclipse from start to finish.

Totality falls on the evening of January 31st for eastern Asia and the far Pacific. China, Mongolia, Japan, Korea, Russia, New Zealand, the Philippines, and most of Indonesia and Australia will see the eclipse in its entirety. (Perth, you miss the opening minutes of the event, but this is no big deal as the subtle shadow in the early stages of a total eclipse isn't visible to the naked eye.)

The map and diagram with timetable on the facing page will give you an idea of what to expect at your location.

## Stages of the Eclipse

There are five stages of a total lunar eclipse. The first stage begins the moment the Moon's leading edge slips into the penumbra. Because the Sun isn't a point source, the cone-shaped shadow cast by the Earth has two components: the penumbra and umbra. The penumbra shadow is about 17,000 km (10,600 miles) wide and is the lighter of the two, cast when Earth covers only part of the Sun. We won't see any of this happen, though, as the shading isn't detectable until it's about halfway across the Moon. Look for a darkening on the eastern side of the Moon.

Penumbral shading becomes deeper as the Moon moves toward the first partial phase, which begins when the Moon's leading edge enters Earth's umbra. The umbral shadow cone extends some 1.4 million km (870,000 miles); at the distance of the Moon's orbit, the cone's width is about 9,000 km (5,600 miles). When the Moon is within Earth's umbral cone, no direct sunlight falls on its surface, so the umbra is darker than the penumbra.

The third stage of the eclipse, totality, starts when the trailing edge of the Moon enters the umbra. Timing this can be iffy, as the Moon's edge isn't as clearly defined as that of a smooth sphere, but once the last peak is in the umbra, totality begins. The length of totality for this year's lunar eclipse will be 1 hour 16 minutes, slightly longer than the one in 2015, which lasted 1 hour 12 minutes. The longest duration of totality for a lunar eclipse is about 1 hour 45 minutes.

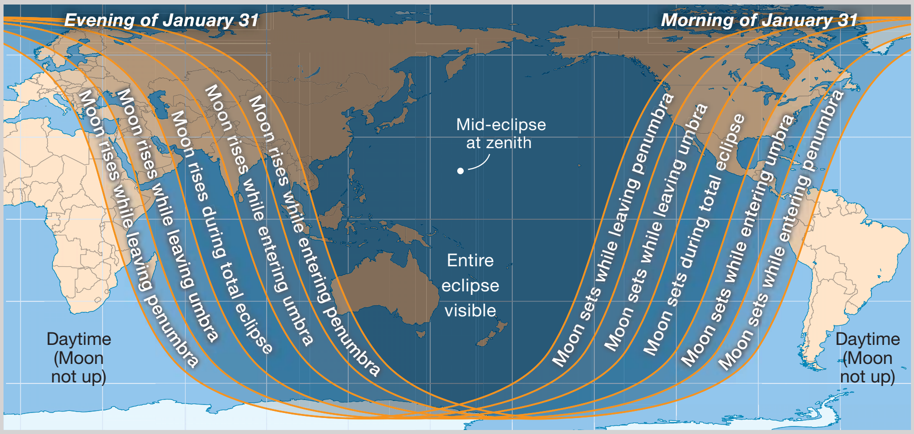
As the trailing edge of the Moon slips out of the umbra, we reverse the play, moving from totality through a second partial and then penumbral phase.

## A Stellar Setting

No two lunar eclipses are the same. You may notice that the umbra isn't completely dark, even during totality. This is due to the refraction of sunlight by Earth's atmosphere, which gives the shadow an orange hue. This bending of the sunlight produces colorful sunrises and sunsets on Earth. The color seen during a lunar eclipse is also affected by how deeply the Moon goes into the umbra, as the umbra's center is darker than its edges. Atmospheric conditions can affect the hue; for example, ash from a volcanic eruption can result in a darker red, gray, or black color.

Look around the sky during totality. Regulus, the brightest star in Leo, will be some 20° left of the eclipsed Moon. The Beehive Cluster (M44) will be around 5° upper right of the Moon.

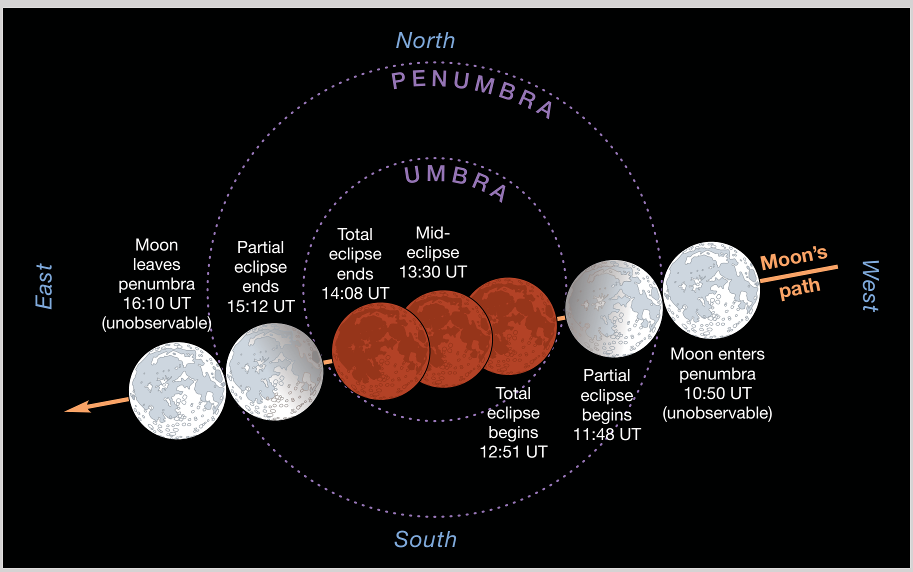
There will be one more lunar eclipse in 2018, but it won't be visible from North America. Central Africa and central Asia will have prime viewing for the July 27th event.




▲ For your location, check whether the Moon will rise or set during some stage of the eclipse. An eclipsed Moon is always full, so the Sun sets or rises at almost the same time on the opposite horizon. This means that a lunar-eclipse moonrise always happens in a very bright sky.

### Total Eclipse of the Moon, January 31, 2018

| Eclipse Event | EDT | CDT | MDT | PDT |
|---|---|---|---|---|
| Penumbra first visible | 6:20 a.m. | 5:20 a.m. | 4:20 a.m. | 3:20 a.m. |
| Partial eclipse begins | 6:48 a.m. | 5:48 a.m. | 4:48 a.m. | 3:48 a.m. |
| Total eclipse begins | — | 6:51 a.m. | 5:51 a.m. | 4:51 a.m. |
| Mid-eclipse | — | — | 6:30 a.m. | 5:30 a.m. |
| Total eclipse ends | — | — | 7:08 a.m. | 6:08 a.m. |
| Partial eclipse ends | — | — | — | 7:12 a.m. |
| Penumbra last visible | — | — | — | 7:41 a.m |




LEAH TISCIONE / S&T (2)

# Regulus Puts on a Show

**THE SAME WANING** gibbous Moon that interferes with the Quadrantid meteor shower offers a spectacle the very next night. An occultation of 1st-magnitude Regulus occurs over northern North America on the night of January 4–5. Optical aid will help you catch the star's disappearance behind the Moon's bright limb, but reappearance at the dark limb will be easier. For those on the southern edge of the event path, Regulus only just meets the Moon, producing a grazing occultation. The graze line extends from southeast Alaska, across central Canada through northeast Ontario, and on past the Maritimes. A good graze offers a dramatic light show, with the star blinking on and off as lunar peaks and valleys pass in front of it. Some timings: **Anchorage,** *disappearance,* 9:42 p.m., *reappearance,* 10:22 p.m. AKST; **Juneau,** *d.* 9:47 p.m., *graze* 9:58 p.m., *r.* 10:14 p.m. AKST; **Whitehorse,** *d.* 10:45 p.m., *r.* 11:22 p.m. PST; **Yellowknife,** *d.* 11:54 p.m., *r.* 12:36 a.m. MST; **Churchill,** *d.* 1:12 a.m., *g.* 1:27 a.m., *r.* 1:45 a.m. CST; **St. John's, NL,** *d.* 4:39 a.m., *g.* 5:05 a.m., *r.* 5:18 a.m. NST.

# Alaska for Aldebaran

**FAR NORTHWEST** North America will see the gibbous Moon, its face 80% sunlit, occult Aldebaran on Saturday, January 27th. Alaska, Canada, and the Pacific Northwest see the event during the early morning hours, while much of central and southern Asia see a daylight occultation. Prime evening visibility happens over north-central Asia.

It may be winter, it may be early hours for North America, but at least dark-sky occultations are easy to observe. This is especially true when the star disappears behind the Moon's dark limb, as it does whenever the Moon's in a waxing phase, as it will be on the 27th.

The Moon travels through an angle roughly equal to its own diameter in an hour, so the longest duration of an occultation (the time between the disappearance of a star at one lunar limb and reappearance at the opposite limb) is also about an hour. For this occultation, observers at the western edges of the visibility zone will see only the disappearance of the 1st-magnitude star, as the Moon sets only a few to some 30 minutes afterward. Viewing conditions are best for Alaskans, who can watch the disappearance and reappearance before the Moon sets around 5:40 a.m. local time.

Some timings: **Anchorage,** *disappearance,* 1:53 a.m., *reappearance,* 2:50 a.m. AKST; **Vancouver,** *d.* 3:11 a.m. PST; **Seattle,** *d.* 3:13 a.m. PST; **Edmonton,** *d.* 4:04 MST.

## Minima of Algol

| Dec. | UT | Jan. | UT |
|---|---|---|---|
| 1 | 2:27 | 1 | 15:28 |
| 3 | 23:16 | 4 | 12:17 |
| 6 | 20:05 | 7 | 9:06 |
| 9 | 16:55 | 10 | 5:56 |
| 12 | 13:44 | 13 | 2:45 |
| 15 | 10:33 | 15 | 23:34 |
| 18 | 7:22 | 18 | 20:23 |
| 21 | 4:11 | 21 | 17:13 |
| 24 | 1:00 | 24 | 14:02 |
| 26 | 21:49 | 27 | 10:51 |
| 29 | 18:39 | 30 | 7:41 |

These geocentric predictions are from the recent heliocentric elements Min. = JD 2445641.5540+ 2.86732400E, where E is any integer. For a comparison-star chart and more info, see **skyandtelescope.com/algol.**

# Action at Jupiter

**TWO MONTHS PAST** solar conjunction, Jupiter opens the year in Libra, where it lingers with Mars in the early morning hours. The duo comes together for a close conjunction on the mornings of January 6th and 7th. Jupiter rises earlier and earlier each morning, brightening just a bit over the course of the month, from magnitude –1.8 to –2.0, and increasing from 33″ to 36″ at its equator.

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

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

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.)

**January 1,** 5:46, 15:42; **2,** 1:38, 11:34, 21:29; **3,** 7:25, 17:21; **4,** 3:17, 13:12, 23:08; **5,** 9:04, 19:00; **6,** 4:55, 14:51; **7,** 0:47, 10:43, 20:38; **8,** 6:34, 16:30; **9,** 2:26, 12:21, 22:17; **10,** 8:13, 18:08; **11,** 4:04, 14:00, 23:56; **12,** 9:51, 19:47; **13,** 5:43, 15:39; **14,** 1:34, 11:30, 21:26; **15,** 7:21, 17:17; **16,** 3:13, 13:09, 23:04; **17,** 9:00, 18:56; **18,** 4:52, 14:47; **19,** 0:43, 10:39, 20:34; **20,** 6:30, 16:26; **21,** 2:22, 12:17, 22:13; **22,** 8:09, 18:04; **23,** 4:00, 13:56, 23:51; **24,** 9:47, 9:43; **25,** 5:39, 15:34; **26,** 1:30, 11:26, 21:21; **27,** 7:17, 17:13; **28,** 3:09, 13:04, 23:00; **29,** 8:56, 18:51; **30,** 4:47, 14:43; **31,** 0:38, 10:34, 20:30.

These times assume that the spot will be centered at System II longitude 285°. If the Red Spot has moved elsewhere, it will transit 1⅔ minutes earlier for each degree less than 285° and 1⅔ minutes later for each degree more than 285°.

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

# Bad Year for the Quadrantids

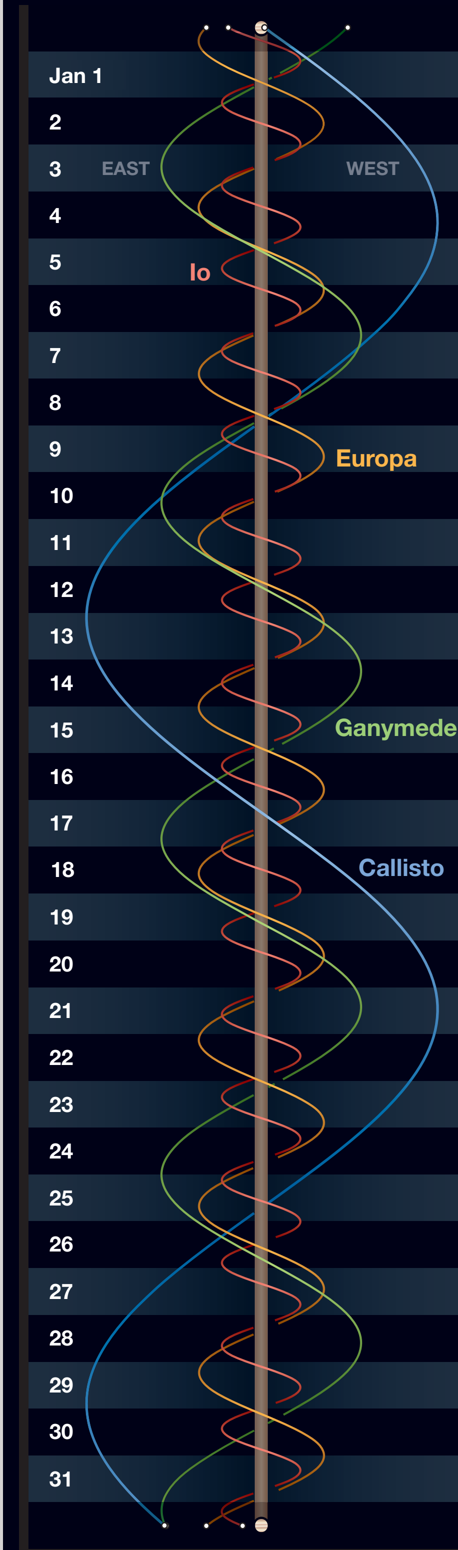
**THE YEAR OPENS** with a whimper as far as meteor showers are concerned, with less than optimal viewing conditions for the annual Quadrantids. Typically, this shower's *zenithal hourly rate* (the number of meteors visible when the radiant is at the zenith in a sky with a limiting magnitude of 6.5) reaches as high as 100, but this ideal output is balanced by a very narrow window for peak activity. For 2018, this translates to a washout, or at least a "Moon-out." The predicted peak for the Quadrantids falls early on the evening of January 3rd, putting the shower in direct competition with light from a quite fat, 96%-lit, waning gibbous Moon.

## Phenomena of Jupiter's Moons, January 2018

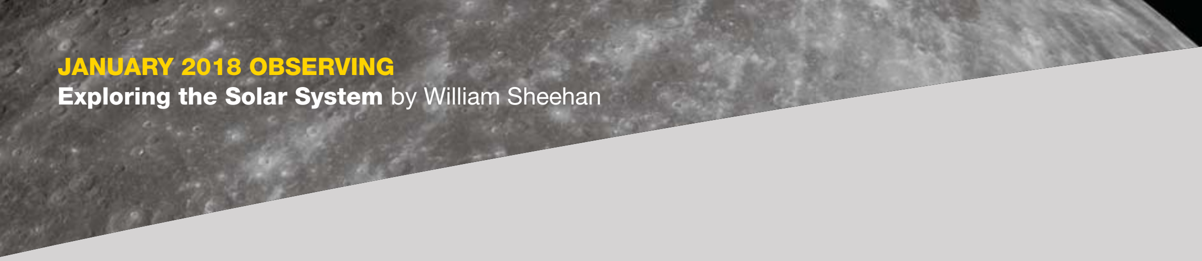
| | | |
|---|---|---|
| Jan. 1 | 12:00 | III.Ec.D |
| | 13:17 | II.Sh.I |
| | 13:52 | III.Ec.R |
| | 14:07 | I.Ec.D |
| | 15:15 | II.Tr.I |
| | 15:33 | II.Sh.E |
| | 16:05 | III.Oc.D |
| | 17:17 | I.Oc.R |
| | 17:30 | II.Tr.E |
| | 17:51 | III.Oc.R |
| Jan. 2 | 11:21 | I.Sh.I |
| | 12:21 | I.Tr.I |
|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

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

## Jupiter's Moons




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



# The Poles of Mercury

Observers once dreamed of 11-mile-high mountains and glittering ice caps.

Mercury — small, elusive, and usually hidden in the solar glare — is the most difficult of the naked-eye planets. Even at the best observing opportunities, it never appears more than 12 arcseconds in diameter, when its night hemisphere is turned toward Earth. At *dichotomy,* when the planet appears half lit, its apparent diameter is a mere 7 arcseconds, half that of Mars at one of its distant (aphelic) oppositions. Small wonder, then, that discoveries about the innermost planet were long few and far between.

The first definite result of telescopic reconnaissance was by Johann Hieronymus Schröter, one of the most enthusiastic observers of the Moon and planets who ever lived. Using a 19-inch reflector, he found, on several occasions in 1800–01, something peculiar about Mercury's southern cusp. Around dichotomy at its greatest eastern elongation from the Sun, it appeared blunted compared to its northern counterpart. By analogy with similar appearances he'd previously noted on Venus, he interpreted the blunting as due to an enormous shadow cast by an 11-mile-high mountain peak.

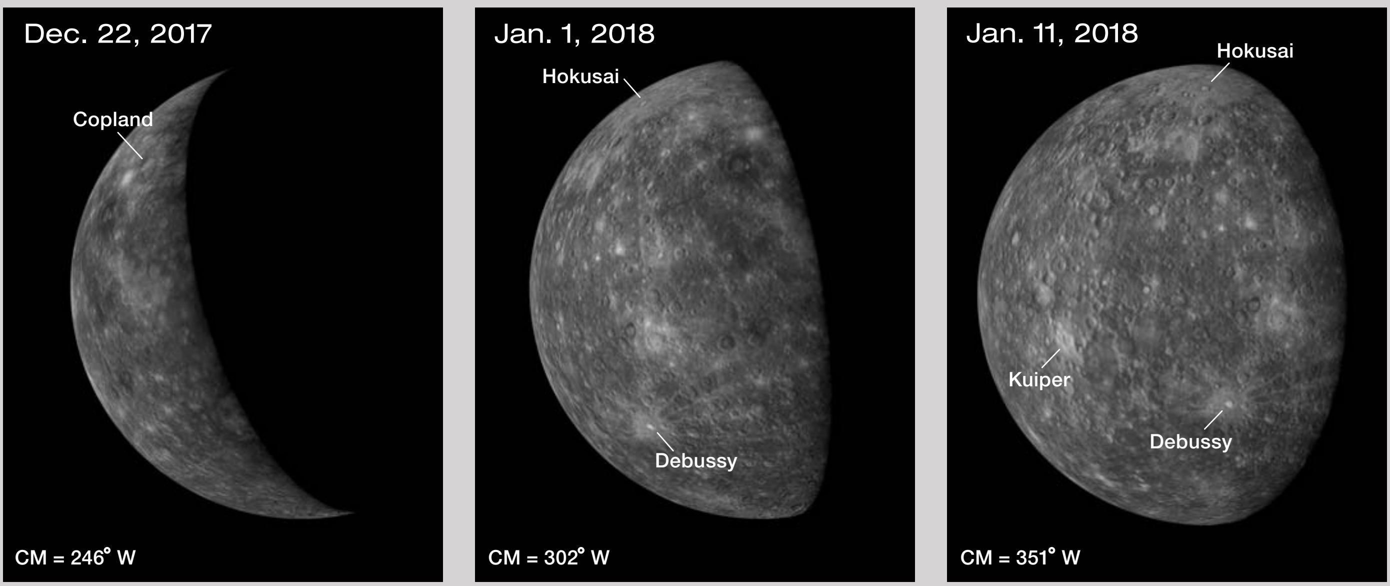
Since Schröter saw the blunted cusp from one night to the next (though not at every evening elongation), he concluded that Mercury had an Earthlike rotation of 24 hours. Occasionally other observers confirmed seeing the blunted cusp, reinforcing confidence in Schröter's work (and his rotation period).

Then, in 1889, Giovanni Schiaparelli in Milan threw an astronomical bombshell. After a long and careful study of Mercury in broad daylight, he announced that the planet's true rotation period was 88 days, the same as the period of revolution around the Sun. This implied that part of the planet must always face the Sun and another part away, though because of Mercury's highly elliptical orbit and resulting libratory sway, an intermediate region, or "twilight zone," would be exposed to alternating conditions of light and shadow.

Certain about the rotation period, and puzzled by changes in the surface features over time that included variable bright spots (clouds?), Schiaparelli concluded that the planet might have a considerable atmosphere. Well-respected observers Eugène Michel Antoniadi and Audouin Dollfus later apparently confirmed this result.

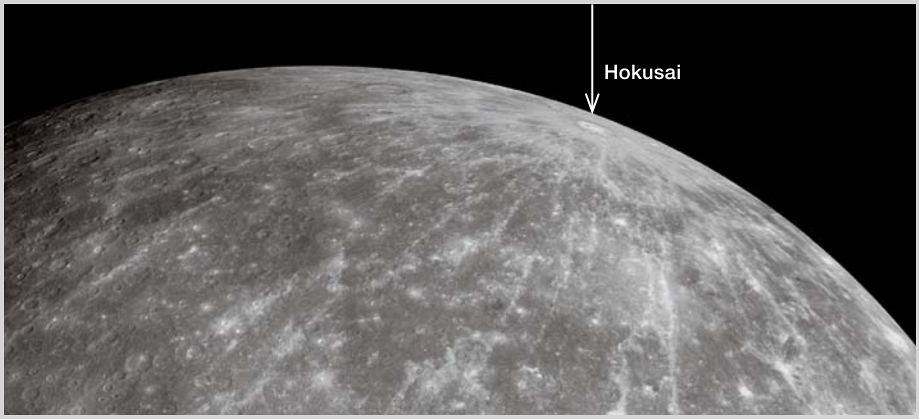
## A New World Revealed

The next bombshell involving Mercury was thrown by radio astronomers 76 years after Schiaparelli published his seemingly ironclad result. Visual observ-




▲ These simulations show Mercury's appearance during its favorable morning apparition in late December 2017 and early January 2018. North is up in all illustrations here; *CM* is the disk's central meridian longitude. The bright-rayed crater Hokusai is at latitude 58°N.

MERCURY COMPOSITES: *WINJUPOS* (3); BANNER IMAGE OF MERCURY: NASA / JHU-APL




▲ NASA's Messenger spacecraft revealed all of Mercury in high resolution. This view shows the impressive pattern of bright rays radiating from Hokusai, a 95-km-wide crater.

ers had been deceived: the planet's true rotation period is only 58.65 days — exactly two-thirds the period of revolution and an example of the dynamic process called *spin-orbit coupling.* The "twilight zone" was gone forever, as was the basis for believing in Mercurian clouds. Any bright or dark patches seen on this relentlessly Sun-baked little world had to be rocks and soil.

Schröter's enormous mountain was also relegated to myth — but the blunting he saw was no figment. As modern hermophiles know, at times the southern cusp *does* appear markedly darker than its northern counterpart. The cusp's dimming is sometimes seen at greatest eastern elongation, sometimes at a western elongation, or it might not be evident at all.

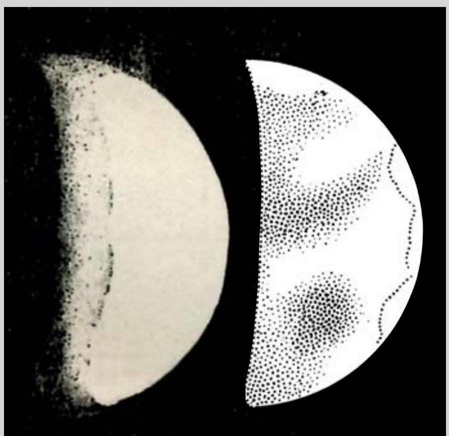
This pattern would not be the case if either Schröter's 24-hour spin or Schiaparelli's 88-day value had been correct. However, it *does* fit the actual 58.65-day rotation period. The spin-orbit coupling means that Mercury completes exactly 1½ rotations each time it orbits the Sun. This presents us with diametrically opposed longitude regions at consecutive eastern or western elongations, causing different features to drift into view over time. Depending on the alignment of darker or lighter albedo features, a cusp might appear blunted — or not.

Meanwhile, many observers over the years have noted *bright* polar regions — especially near the northern cusp. Occasionally these caps were suspected of being snow deposits — not so far-fetched in the era when Mercury was believed to have an atmosphere. In recent years, data from NASA's Messenger orbiter (short for Mercury Surface, Space Environment, Geochemistry, and Ranging) have shown the kernel of truth in these findings.

It turns out that light and dark features are asymmetrically distributed across Mercury's face. In the north is a broad, bright belt of relatively smooth volcanic plains, whose *albedo,* or reflectivity, averages about 0.20 — compared to less than 0.10 for most of the rest of the planet, which is dominated by older, more rugged terrain. (The Moon's surface looks just the opposite; its lava-covered maria appear much *darker* than its ancient highlands.)

The brightness of Mercury's broad northern belt is particularly enhanced in an area of clustered rayed craters near the classical albedo feature Solitudo Aphrodites (280°W, 30°N), and in an area, once known as "Apollonia," centered on the bright-rayed crater Hokusai (18°W, 58°N). The albedos of rayed craters on Mercury are high, 0.36 to 0.40. Consequently, at the low resolution we see telescopically, these bright areas can create the impression of a bright polar cap.

The terrain around the southern pole *is* somewhat duskier than Mercury's average surface, but Schröter's blunted southern horn must have been, in part, an effect of contrast with the brighter northern one. It's not so much the southern horn is blunted as that the northern one protrudes.



**Left:** During intensive observations in 1800–01, Johann Schröter found that the southern cusp of Mercury (at bottom) occasionally appeared blunted.
**Right:** A sketch of Mercury by Eugène M. Antoniadi from the late 1920s.

(Incidentally, we do now know definitively, from ground-based radar and Messenger observations, that water ice lies inside certain perpetually shadowed craters near the poles — such as Prokofiev and Kandinsky in the north, and Chao Meng-Fu in the south. The source of the ice, though still debated, is probably from comets and meteoroids containing hydrated minerals. It has nothing to do, of course, with the "polar caps" reported by visual observers.)

At this month's favorable morning apparition of Mercury, visual observers and CCD imagers are encouraged to sleuth out the north "polar cap" — or, equivalently, Schröter's blunted southern cusp. The planet will rise at least 1½ hours before the Sun from the last week of December until about January 10th.

We now know a great deal about the surface of this fascinating little world, but the impressions of a morning's vigil at the telescope still have a place: They recall a more innocent and fanciful era, when 11-mile-high mountains, clouds, and even snowfields seemed plausible — and no surmise was too strange to lie outside the realm of possibility.

■ **WILLIAM SHEEHAN** is a psychiatrist based in Flagstaff, Arizona, where he dreams about the planets. His new book, *Mercury,* will be published in 2018.

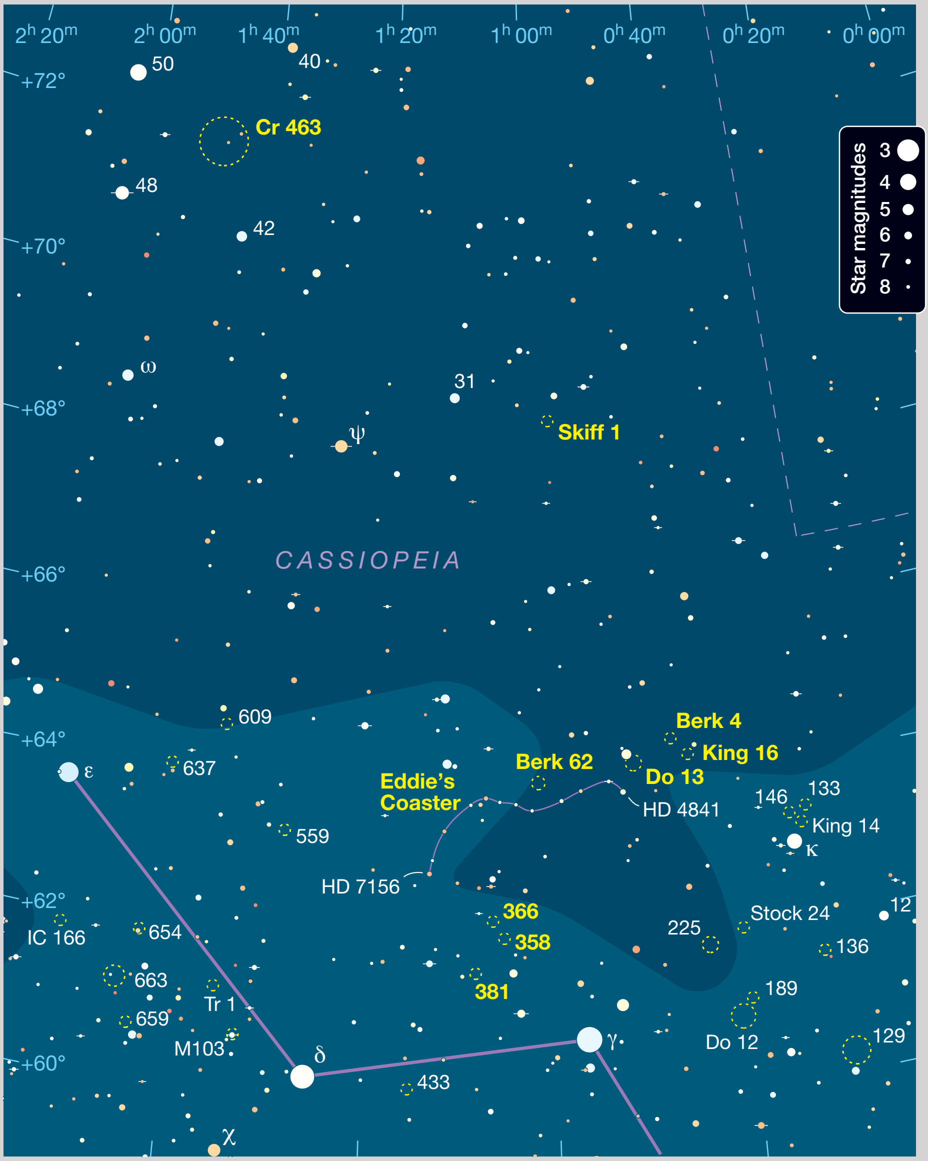
SKETCHES: *SPLENDOUR OF THE HEAVENS* (PHILLIPS, 1925), *LA PLANETE MERCURY* (ANTONIADI, 1934); HOKUSAI CRATER: NASA / JHU-APL

# The Hidden Queen

Follow this map to the lesser-known treasures of Cassiopeia.

Last month we visited some of the finest sights in Cassiopeia, but for those who like to wander off the beaten path, we'll now take a look at some of the lesser-known wonders of the mythological Queen.

Let's begin with a trio of open clusters from the *New General Catalogue of Nebulae and Clusters of Stars* that's centered 1.7° northeast of Gamma (γ) Cassiopeiae. A shallow, 1.4°-long arc of three stars, 5th and 6th magnitude, rests north of Gamma. If you follow it eastward, it will lead you to the most obvious cluster of the crew, **NGC 381**. Through my 105-mm refractor at 36×, it's a rich dusting of very faint stars, with brighter sparks north of the group's center and at its northern edge. Northwestward in the same field of view, **NGC 366** and **NGC 358** join the scene as two small knots of faint stars.




Examining the clusters individually at 174× helps tease out their pinpoint specks of light. NGC 381 is spangled with about 25 moderately faint to very faint stars confined to 7′. NGC 366 offers only six faint to very faint suns arranged in a 2.2′-tall Y, with the base of the Y to the north and its southernmost star a close double. NGC 358 parsimoniously resolves into a 2′ trapezoid of four stars, magnitudes 11.0 to 12.7.

My 10-inch reflector at 213× doubles the number of stars in NGC 366, with its glimmering Y sprawled across the eastern half of the 3′-wide group. NGC 358 gains two extremely faint stars. A line between them would run north-northwest to south-southeast and bisect the trapezoid. All six stars make a 2′ D, belly southwest.

Although close together on the sky, these star groups were discovered by different observers at widely spaced times. Not surprisingly, they were found in chronological order from most to least prominent. William Herschel swept up NGC 381 in 1787, and his son John Herschel discovered NGC 366 in 1829. Heinrich d'Arrest spotted NGC 358 in 1865 while observing NGC 366. As you might suspect from its appearance, NGC 358 is most likely an asterism rather a cluster. Despite this ignoble standing in the field of astronomy, it gains some small claim to fame in *Invasion of the Star System NGC 358*, a science-fiction novel by Leon McDonald and Yomanaa Khieowong. Strangely, the distance to their star system is given as a mere 11.8 light-years.

Climbing 1.8° north-northwest from NGC 366 takes us to **Berkeley 62**, one of 85 original discoveries by Arthur F. Setteducati and Harold F. Weaver of the University of California, Berkeley. They published their findings in a two-part, 1962 paper entitled "Newly Found Star Clusters."

Berkeley 62 is an obvious, fairly small hazy patch bearing a few very faint stars through the 105-mm scope at 28×. A magnification of 127× shows a straight line of three faint, equally spaced stars that leans east-northeast. To its north sits a six-star curve, concave toward the north-northwest, including the cluster's brightest star shining at magnitude 10.8. Three very faint stars are also visible. The 10-inch scope at 166× shows about 40 stars down to magnitude 14½ within the 10′ diameter given by Setteducati and Weaver.

Close to Berkeley 62, you'll find the binocular asterism **Eddie's Coaster**, named for Eddie Carpenter, the longtime British observer who first noticed it. Stretching across 2.8° of sky, the double-peaked rollercoaster consists of 7th- to 9th-magnitude stars, so don't be distracted by the brighter stars surrounding it. About 20 stars form the coaster's track, as viewed through 12×36 binoculars from my semirural home. Berkeley 62 sits north of the track's valley. To the east the track rises slightly before plunging southward to 7.3-magnitude HD 7156 glittering near the coaster's end. West of the valley, the track climbs a less pronounced peak and then turns down a bit, offering a milder ride at the coaster's start.

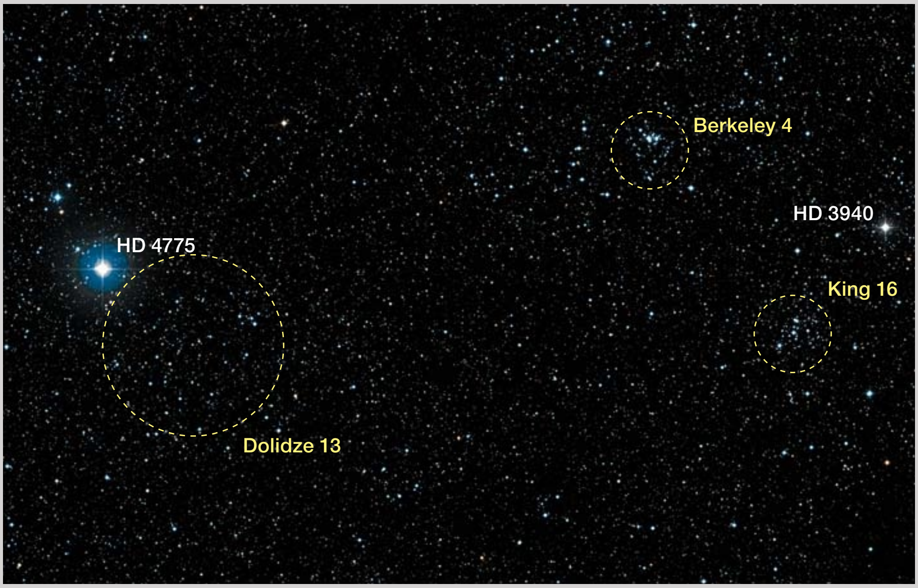
Like a big carnival balloon, **Dolidze 13** floats 23′ north-northwest of HD 4841, the 6.9-magnitude star that marks the beginning of Eddie's Coaster. The 105-mm refractor at 47× shows a pretty swarm of gleaming motes spanning about 12′. A 5.4-magnitude, yellow-white star nuzzles the group's northeastern edge. My 10-inch reflector shows about 25 stars loosely sprinkled across 13′.

Unlikely as it seems that such a scattered collection of stars is a true cluster, Dolidze 13 appears in a 2016 cluster catalog by Nina V. Kharchenko and colleagues. They assign an 8,000-light-year distance and a 900-million-year age.

The 47× view of Dolidze 13 in the refractor includes **King 16** and **Berkeley 4**, small knots of stars that are easy to overlook. A 4½′-wide smile of five 10th- and 11th-magnitude stars rests 5′ east-southeast of Berkeley 4. At 153× King 16 displays six faint to very faint stars arranged in the shape of a skinny V whose northeastern arm is caved inward and marked by a double star at its end. At 174× Berkeley 4 reveals an arc of five stars, the westernmost a close double, plus a sixth star south of the arc.

In the 10-inch reflector at 70×, all but the base of King 16's V is enshrined


▲ The brightest stars of the open cluster NGC 358 form a letter D, or perhaps a heavy-lidded eye, when viewed through the telescope. Move to the northeast, skirting a trio of orange 13th–15th magnitude twinklers, to find the more populous NGC 366.



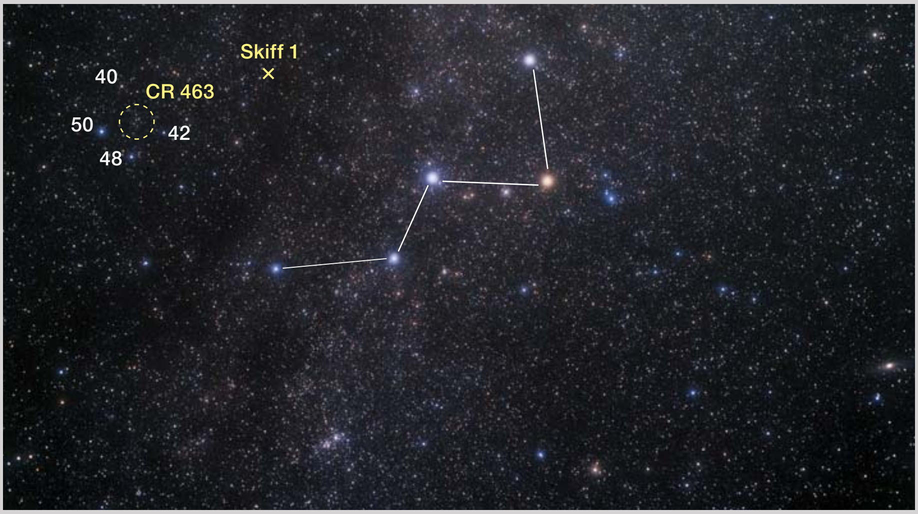

▲ Fifth-magnitude HD 4775 marks the northeastern edge of the open cluster Dolidze 13. The cluster King 16 lies less than 1° west of Do 13 and about 9′ southeast of 7th-magnitude HD 3940. Berkeley 4 sparkles just 5′ northeast of King 16, looking like an upside-down Y.

TOP: MARTIN GERMANO; BOTTOM: POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY in haze, which becomes granular at 118×. At 192× a dozen stars precipitate from the haze amid lingering scraps of mist. Altogether they cover about 3′. Surveying Berkeley 4 at 118×, I see 20 stars forming a southward-pointing arrowhead almost 4′ long.

King clusters are named for astronomer Ivan R. King. As a Junior Fellow at Harvard College Observatory, King had access to plates of the sky surveys taken with the 16-inch Metcalf and 24-inch Bruce refractors. He says they were fun to look at, and he began to notice clusters that had never been cataloged. His first 21 objects were published in the observatory's bulletin in 1949, although King 3 turned out to be a previously discovered object.

Leaping farther northward we'll address the open cluster **Skiff 1**, found by professional and amateur astronomer Brian Skiff. Skiff noticed the group while making visual classifications of galaxies on POSS-II films. It's an ancient cluster with an age of about 1.2 billion years. The apparent boundaries of Skiff 1 include the red giant V1267 Cas, a semi-regular variable whose visual magnitude is usually given as 12 to 12½. The star probably dwells in the cluster's background.

Skiff 1 shows a granular hazy patch about 6′ across through my 105mm scope at 87×. The group's brightest star, 10th magnitude, stands out in the west, accompanied by a 12th-magnitude star 41″ to its southeast. V1267 Cas is visible north of center, and a few extremely faint stars sparkle in and out of view. About 30 stars, mostly faint to extremely faint, peek out for the 10-inch scope at 192×. They coalesce into a 7′ group with a nearly starless void south-southwest of the group's center.




▲ The open cluster Collinder 463 is relatively easy to find: Just draw an imaginary trapezoid using the stars 40, 42, 48, and 50 Cassiopeiae as the corners, then look inside. Treasure! Collinder 463 lies about 2,300 light-years away from us.

AKIRA FUJII

Our final stop is **Collinder 463**, a large cluster boxed in by the trapezoid fashioned by 40, 42, 48, and 50 Cassiopeiae, stars visible to the unaided eye from my home. Trapezoid and cluster fit nicely in the 3.7° field of view of 18×50 image-stabilized binoculars, with Cr 463 splashing about 40 stars across nearly 1° of sky. Most of the stars are gathered into 35′-wide bunch and a narrow arm sweeping 15′ northward from its northwestern edge. The brightest gems form a fat crescent, its lucida glowing orange. I count 75 stars with the 105-mm scope at 28×.

Swedish astronomer Per Arne Collinder discovered Cr 463 and included it in his 1931 doctoral dissertation. He noted that it looked like a very good cluster specimen but might simply appear so due to obscuring matter around it. Collinder 463 is now deemed a true cluster.

## Clusters & Asterisms in the Queen

| Object | Type | Dist. (l-y) | Mag(v) | Size/Sep | RA | Dec. |
|---|---|---|---|---|---|---|
| NGC 381 | Open cluster | 3,700 | 9.3 | 7′ | $1^h$ $08.3^m$ | +61° 35′ |
| NGC 366 | Open cluster | 5,800 | 9.8 | 4′ | $1^h$ $06.5^m$ | +62° 14′ |
| NGC 358 | Asterism | — | 10.1 | 3′ | $1^h$ $05.2^m$ | +62° 01′ |
| Berkeley 62 | Open cluster | 6,000 | 9.3 | 10′ | $1^h$ $01.2^m$ | +63° 57′ |
| Eddie's Coaster | Asterism | — | — | 2.8° | $1^h$ $02.3^m$ | +63° 18′ |
| Dolidze 13 | Open cluster | 7,800 | — | 12′ | $0^h$ $50.0^m$ | +64° 08′ |
| King 16 | Open cluster | 6,300 | 10.3 | 5′ | $0^h$ $43.7^m$ | +64° 11′ |
| Berkeley 4 | Open cluster | 8,000 | 10.6 | 4′ | $0^h$ $45.2^m$ | +64° 24′ |
| Skiff 1 | Open cluster | 5,200 | — | 7′ | $0^h$ $58.4^m$ | +68° 28′ |
| Collinder 463 | Open cluster | 2,300 | 5.7 | 57′ | $1^h$ $45.8^m$ | +71° 49′ |

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.

■ Contributing Editor **SUE FRENCH** wishes everyone a star-filled new year.

# Dark Clouds in Taurus

Set yourself a challenge and spend a night or more navigating through nebulae in an under-observed part of the sky.

The finest dark nebulae for telescopes are those that are silhouetted against a bright background, such as the striking, chevron-shaped dark lane within the high surface brightness Carina Nebula, or those silhouetted against the Milky Way's brightest star clouds. One example of the latter is Barnard 92, a foreground object in front of distant M24 (the Small Sagittarius Star Cloud).

Dark nebulae are also detectable in much fainter portions of the Milky Way, but while they may look obvious on images, they're fairly challenging at the eyepiece. Since the Milky Way background is too faint visually to silhouette the dust clouds, they can only be detected by the paucity of faint stars in comparison with the rest of the field or surrounding fields. But note that there may not be a marked shortage of brighter stars since many of them will be closer to us than the dust cloud is.

The *Millennium Star Atlas* (*MSA*), unfortunately out-of-print, has long been my favorite guide for hunting these absorption nebulae. I find that the dark nebulae boundaries on *MSA* charts are usually quite accurate. If I star-hop to the correct location for a Barnard dark nebula, and note a marked decrease in the density of faint stars precisely where the atlas says that I should, then I consider that I have detected something that obscures the more distant stars — that is, a dust cloud absorbing the light of stars located behind it. I see no difference between detecting a dark nebula due to a marked absence of faint stars, and detecting a loose open cluster because of a statistically significant increase in star density at the cluster's plotted position.

The Milky Way is certainly faint in Taurus. Nevertheless, my 8-inch f/6 Dobsonian, working at 30× with a 1.25° field of view, revealed three large winding dust clouds. Spending two nights observing at such low power was very relaxing. On both nights, M33 was visible with the unaided eye, indicating that the transparency was excellent.

The easiest one was **B19–B22**, the 6°-long Taurus Dark Cloud. I could follow all of it, although the northwestern finger was just detectable. There were almost no faint stars visible in the 8-inch between RA $4^h\ 28^m$ and $4^h\ 34^m$, and there was a good southern boundary in that section. East of there the broad dark nebula was still easy to follow since, while there was a smattering of faint stars, there were far more outside of the boundaries plotted in *MSA*. The eastern end, beyond RA $4^h\ 38^m$, was nearly empty of faint stars, and this prominent area continued farther than plotted in *MSA*, all the way to RA $4^h\ 48^m$. This was one of the very few times that a dark nebula has appeared to be significantly larger than plotted in the *MSA*, but Antonin

PHILIPP SALZGEBER

▲ The dark sooty shapes of the nebulae are clearly seen against the starry backdrop in this wide-field photo. The field of view also encompasses well-known objects such as the Pleiades on the right and Aldebaran at the bottom, as well as the open clusters NGC 1746 and NGC 1647, which are both visible with the unaided eye at true dark sites.

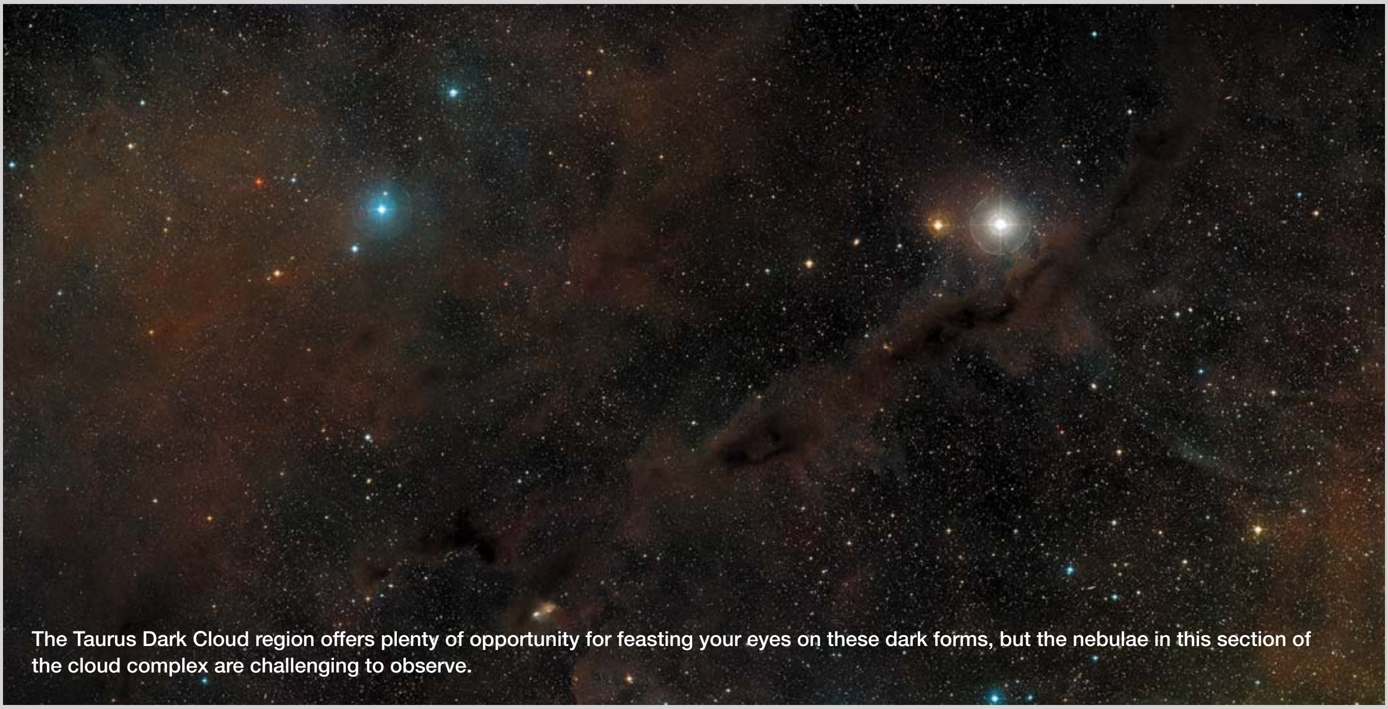
Becvar's classic *Atlas of the Heavens* (1962) shows the dust cloud extending almost as far east as my impression.

Equally long **B219** lies a couple of degrees north of the Taurus Dark Cloud and extends into Auriga. Much of the dark nebula is obvious, and my notes on the chart that I used at the eyepiece say "good" at the western end, "no faint stars" around $4^h 33^m$, "a few faint stars" between RA $4^h 36^m$ and $4^h 40^m$ but "lots" immediately north of the boundary plotted in *MSA*, and then "sparse" in the main body of the dust cloud up to $4^h 47^m$. The boundary north of unseen **B23** and **B24** is "less definite than the southern boundary." The thumb that extends south-southeastwards to declination +27.5° is "all strikingly empty of stars." I found the *MSA* boundaries to be "pretty exact" at the narrowing northwest of the unseen bright nebula vdB 29.

But beyond that neck, as the dark nebula crosses into Auriga, it was only vaguely visible, and the northernmost extension that lies beside the globular cluster Palomar 2 was not seen. While you're in the area do take a look at Palomar 2, which is one of the easiest of the 15 Palomar globular clusters — my 16-inch revealed this averted vision fuzzy blob at only 65×, so it would certainly be visible with a smaller scope.

South of the Taurus Dark Cloud my 8-inch at 30× showed all of 1.7°-long **B18**, looking a little larger than charted, as well as barely discernible **B208**, by far the thinnest of any of my successes.

The parts of winding **B7–B209–B211** that my 8-inch could mostly reveal are 4.5° long and lie immediately west of the Taurus Dark Cloud. The star


The Taurus Dark Cloud region offers plenty of opportunity for feasting your eyes on these dark forms, but the nebulae in this section of the cloud complex are challenging to observe.

fields are sparser outside of the plotted boundaries of B7-B209-B211 than they are adjacent to the other two large dust clouds, so this dark nebula is harder to follow at the eyepiece. The western tip was starless, but the adjacent section immediately south of Psi (ψ) Tauri was too narrow to detect. The loop southwards around RA $4^h\,09^m$ was just "slightly sparse in stars," and the northwest-pointing thumb beside it was logged as "uncertain," although it looks prominent on plate 5 in E. E. Barnard's *Photographic Atlas of Selected Regions of the Milky Way* (**https://is.gd/Plate5**).

The view improved farther eastward, the faint stars becoming "sparse" between RA $4^h\,12^m$ and $4^h\,15^m$, and then "nearly empty" until B211 passed Phi (φ) Tauri. The thin neck just west of Phi looked wider than it's plotted in *MSA*. Phi is a wide yellow and blue double star of magnitudes 5.1 and 7.5, easy to split even at 30×. I couldn't follow this complex of Barnard nebulae southeast of Phi with my 8-inch, but nine years earlier I saw little **B213** and **B216** with my 16-inch at 76×. Both are much smaller dark nebulae than any that the 8-inch could find in this area.

Observing the Taurus Dark Cloud and the other two large winding dust clouds isn't exceptionally difficult, but I haven't read of any other reported observations except for Nova Scotian Paul Gray's detection of the thin neck in B211 near Phi Tauri. Perhaps it was just generally assumed that the Taurus Dark Cloud was not detectable visually? It's certainly been a popular target for astrophotographers — see Chris Schur's image in the Gallery in the April 2015 issue of *Sky & Telescope* (pp. 78–79).

## Barnard's Nebulae in Taurus

| Object | Opacity | Size | RA | Dec. |
|---|---|---|---|---|
| B19 | 4 | 360′ | $04^h\,33.7^m$ | +26° 16′ |
| B22 | 4 | 360′ | $04^h\,38.7^m$ | +26° 03′ |
| B219 | 3 | 360′ | $04^h\,34.9^m$ | +29° 36′ |
| B23 | 5 | 5′ × 5′ | $04^h\,40.6^m$ | +29° 53′ |
| B24 | 5 | 8′ × 8′ | $04^h\,42.9^m$ | +29° 44′ |
| B18 | 5 | 100′ | $04^h\,31.2^m$ | +24° 21′ |
| B208 | — | 60′ × 8′ | $04^h\,11.5^m$ | +25° 10′ |
| B7 | 5 | 60′ × 60′ | $04^h\,17.4^m$ | +28° 34′ |
| B209 | 5 | 120′ × 30′ | $04^h\,12.4^m$ | +28° 20′ |
| B211 | 5 | 60′ × 20′ | $04^h\,17.2^m$ | +27° 49′ |
| B213 | 5 | 30′ | $04^h\,21.2^m$ | +27° 03′ |
| B216 | 5 | — | $04^h\,24.0^m$ | +26° 38′ |

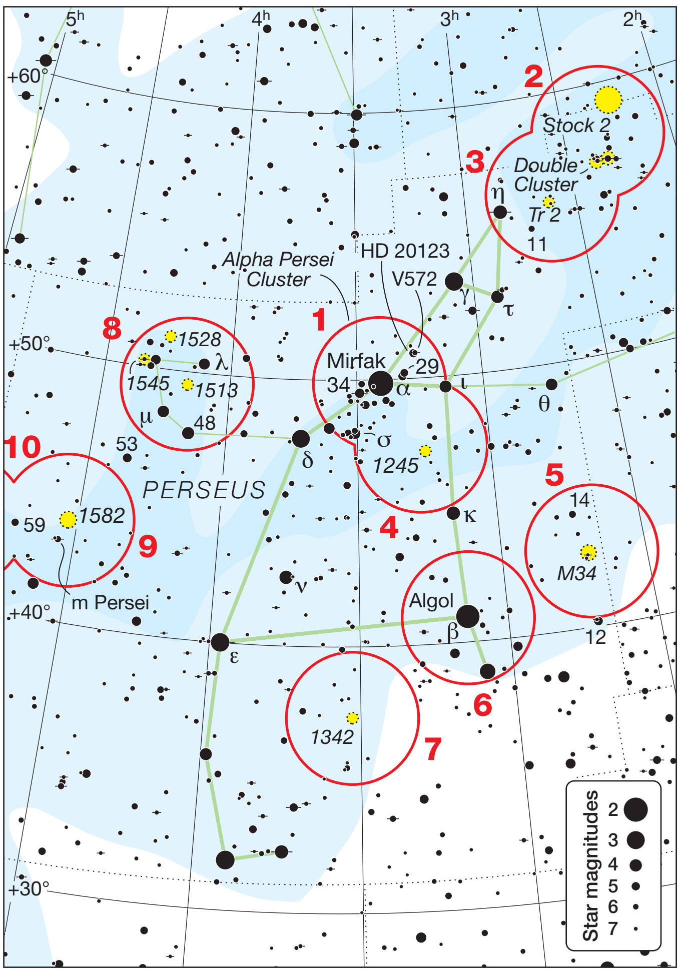
Angular sizes and separations are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.



■ *Sky & Telescope* has been a special part of Contributing Editor **ALAN WHITMAN**'s life for many decades.

# Open Clusters Galore

**Point your binoculars toward Perseus and Auriga, and prepare to be dazzled by a myriad of clusters.**




GREGG DINDERMAN / S&T, SOURCE: *SKY & TELESCOPE'S POCKET SKY ATLAS*

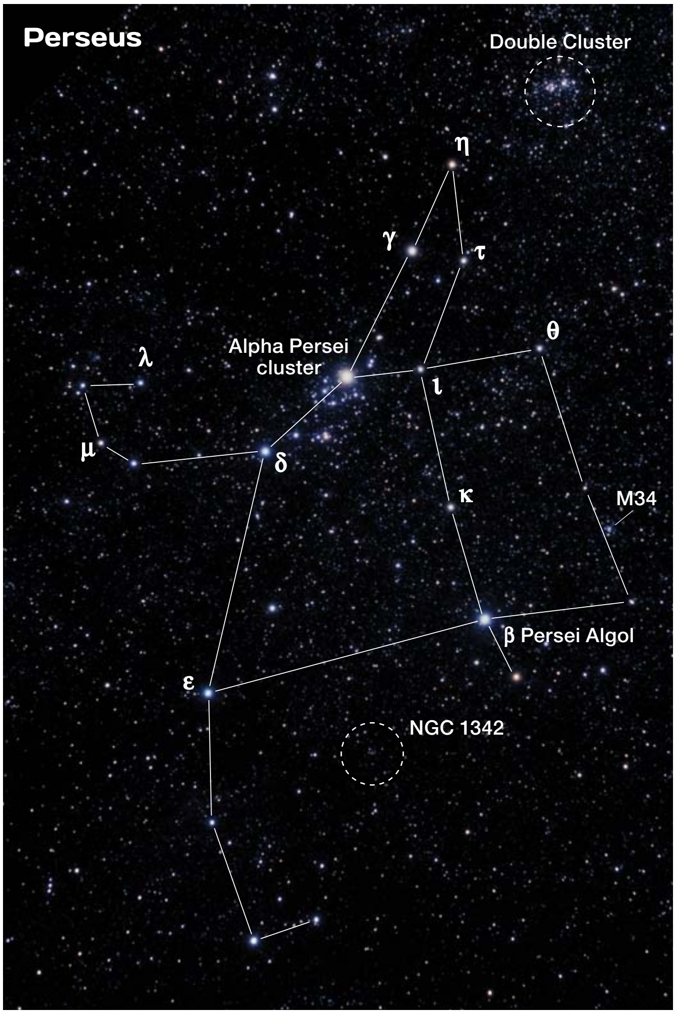
**People often ask me** if spending so much time out under the stars makes me feel insignificant. My answer is, "Yes and no." Exploring the night sky — getting to know the clusters, nebulae, and galaxies that really are out there, as factual as my morning toast — certainly makes my problems seem insignificant. But stargazing also makes me feel proud of *Homo sapiens* as a species, that we have reached out and grasped so much with nothing more than polished glass and primate cleverness.

The winter Milky Way is a good place to make that visual and conceptual leap. In previous binocular tours I covered the Milky Way from Canis Major, the Big Dog, to Hydra, the Water Snake (*S&T*: Dec. 2015, p. 32), and Monoceros, the Unicorn, to Gemini, the Twins (*S&T*: Mar. 2017, p. 30). In this installment, we'll visit the constellations Perseus, the Greek hero, and Auriga, the Roman charioteer. In doing so, we'll look outward from our own Orion Spur to the neighboring Perseus Arm of the Milky Way. As we observe the open clusters that dot both constellations, we will trace the physical structure of our galaxy.

Binoculars and rich-field telescopes are great for this kind of exploration — with their low magnifications and wide fields, they sweep up enough sky to put deep-sky objects into context. I made these observations with 15×70 binoculars that have a 4.4° true field of view, but almost all of the objects on this tour will be visible in 10× or even 7× instruments. Whatever you have handy will probably serve, so let's venture forth.

Every tour needs a port of departure, and the bright star Alpha (α) Persei and its associated cluster will serve as ours.

BACKGROUND: BABAK TAFRESHI; CONSTELLATION DRAWINGS: HEVELIUS




▲ **GREEK HERO** You will find Perseus is resplendent in the winter sky, adorned with a myriad of clusters and other interesting binocular targets.


▲ **TINY DAZZLER** This is a little-known cluster in a well-known part of the sky. Look for NGC 1342 in Perseus's legs.

The **Alpha Persei Cluster** (Stop 1 on the map on p. 60) is a true open star cluster, and as it sprawls across 5°, it's one of the few deep-sky objects that's better appreciated with binoculars than with a telescope. The cluster appears so large in part because it is close — only about 600 light-years away, still within the Orion Spur with us — and in part because it's inherently huge. Most open star clusters are between 10 and 25 light-years in diameter, but the Alpha Persei Cluster is a monster, fully 50 light-years across.

The Alpha Persei Cluster has plenty of easy, pretty double stars for binocular observers. In particular, check out the wide pair of **29** and **31 Persei** less than 1° west of Alpha Persei, and the closer pair of **HD 20123** and **V572 Persei** another degree to the north. Southeast of Alpha, **Sigma (σ) Persei** is a nice binocular multiple, dominated by a distinctly yellow *K*-type giant.

Our next stop probably needs no introduction: Sweep 11° northwest of Alpha Persei to find the famous **Double Cluster**, **NGC 869** and **NGC 884** (Stop 2), one of the finest binocular sights in the entire sky. Chances are you've seen this pair of celestial gems before, probably many times. Whether it's your first visit or your hundred-and-first, here are some things to look for. Start by noting the differences between the two clusters. NGC 869 has a dense center rich with bright stars. By contrast, NGC 884 at first looks empty, with a dark center surrounded by a ring of brighter stars. Patience and dark adaptation will reveal that the empty center is in fact spangled with a myriad of fainter suns. Next, see if you can detect any color in the stars of the two clusters. Both clusters have a few red giants scattered among their otherwise mostly blue-white members.

Finally, follow the chain of bright stars that arcs north from NGC 869 to the open cluster **Stock 2**, the bright stars of which form an almost perfect stick-figure. I tend to see Stock 2 as Tarzan, swinging on the "vine" of stars that leads back to NGC 869.

While you are in this neck of the woods, don't neglect the open cluster **Trumpler 2** (Stop 3). The brighter stars of the cluster form a shallow sickle shape with horns pointing at the Double Cluster and Eta (η) Persei.

Nature rarely draws in straight lines, but she must have broken out the straightedge when Perseus was formed. From Trumpler 2, a nearly perfect line of progressively brighter stars leads south and east, including 11 Persei, Tau (τ) Persei, and Iota (ι) Persei. That line is echoed with an even brighter line just to the east, made up of Eta Persei, Gamma (γ) Persei, and Alpha Persei. Iota and Alpha Persei make an equilateral triangle with the open cluster **NGC 1245** (Stop 4). NGC 1245 is very distant for an open cluster — over 9,000 light-years, 15 times the distance to the Alpha Persei Cluster. It's a tough catch in smaller instruments and looks nebulous and unresolved at less than 15×.

Our next target is the open cluster **M34** (Stop 5). Before you attempt it with binoculars, try to spot it with your naked eyes. The key to picking out this close, bright cluster lies with

TOP: AKIRA FUJII; BOTTOM: JIM THOMMES

## Through Perseus and Auriga

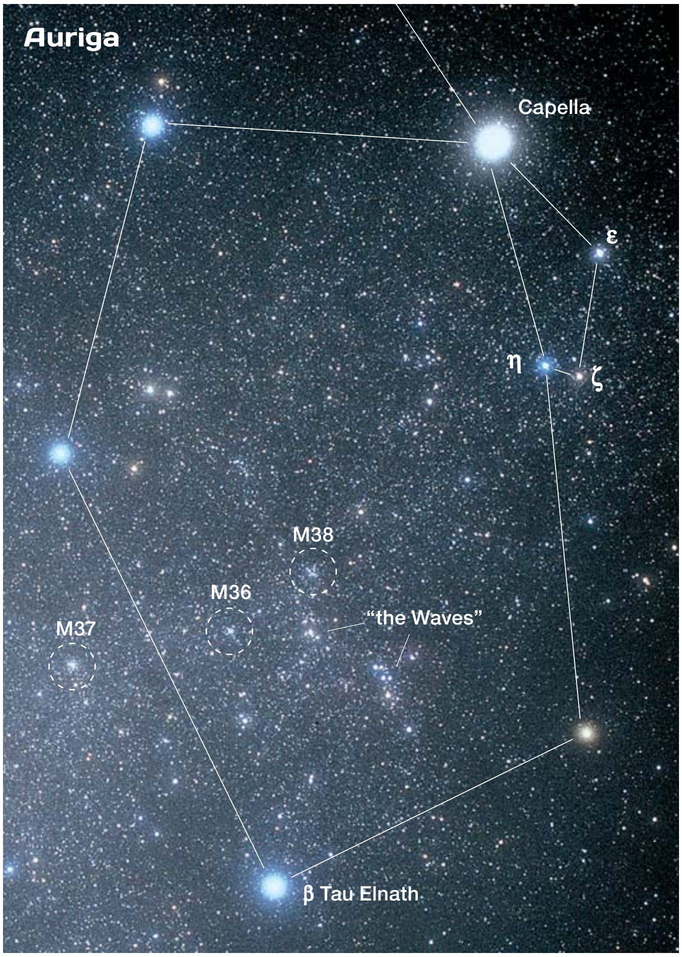
| Object | Type | Mag(v) | Size/Sep | RA | Dec. |
|---|---|---|---|---|---|
| Alpha Persei Cluster | Open cluster | 2.3 | 300′ | $03^h$ $25.6^m$ | +49° 55′ |
| 29 and 31 Persei | Optical double | 5.2, 5.0 | 370″ | $03^h$ $20.4^m$ | +50° 09′ |
| HD 20123 & V572 Persei | Optical double | 5.1, 6.6 | 87″ | $03^h$ $17.5^m$ | +51° 00′ |
| Sigma Persei | Optical double | 4.3, 5.8 | 396″ | $03^h$ $31.8^m$ | +48° 03′ |
| NGC 869 | Open cluster | 5.3 | 18′ | $02^h$ $20.3^m$ | +54° 25′ |
| NGC 884 | Open cluster | 6.1 | 18′ | $02^h$ $23.7^m$ | +57° 12′ |
| Stock 2 | Open cluster | 4.4 | 60′ | $02^h$ $16.0^m$ | +59° 34′ |
| Trumpler 2 | Open cluster | 5.9 | 17′ | $02^h$ $28.2^m$ | +55° 58′ |
| NGC 1245 | Open cluster | 8.4 | 32′ | $03^h$ $15.9^m$ | +47° 18′ |
| M34 | Open cluster | 5.2 | 35′ | $02^h$ $43.2^m$ | +42° 49′ |
| Algol (Beta Persei) | Variable star | 2.1 | — | $03^h$ $09.3^m$ | +41° 01′ |
| NGC 1342 | Open cluster | 6.7 | 15′ | $03^h$ $32.8^m$ | +37° 25′ |
| NGC 1528 | Open cluster | 6.4 | 16′ | $04^h$ $16.7^m$ | +51° 14′ |
| NGC 1545 | Open cluster | 6.2 | 18′ | $04^h$ $22.3^m$ | +50° 17′ |
| NGC 1513 | Open cluster | 8.4 | 10′ | $04^h$ $11.3^m$ | +49° 33′ |
| NGC 1582 | Open cluster | 7.0 | 24′ | $04^h$ $32.9^m$ | +43° 46′ |
| m Persei | Binary star | 6.1, 6.8 | 121″ | $04^h$ $34.7^m$ | +43° 06′ |
| NGC 1664 | Open cluster | 7.6 | 9′ | $04^h$ $52.4^m$ | +43° 42′ |
| NGC 1778 | Open cluster | 7.7 | 8′ | $05^h$ $09.3^m$ | +37° 02′ |
| NGC 1893 | Open cluster | 7.5 | 25′ | $05^h$ $23.9^m$ | +33° 25′ |
| NGC 1907 | Open cluster | 8.2 | 7′ | $05^h$ $29.3^m$ | +35° 20′ |
| M38 | Open cluster | 6.4 | 20′ | $05^h$ $29.9^m$ | +35° 51′ |
| M36 | Open cluster | 6.0 | 10′ | $05^h$ $37.5^m$ | +34° 08′ |
| M37 | Open cluster | 5.6 | 14′ | $05^h$ $53.5^m$ | +32° 33′ |

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.

another double line of stars. First note the nearly straight line formed by Iota, Kappa (κ), and Algol or Beta (β) Persei. That line is echoed 4° to the west by Theta (θ), 14, and 12 Persei. M34 lies just west of the line between 14 and 12 Persei. The cluster's apparent magnitude of 5.5 makes it just about as bright as 14 Persei, which accords well with my own naked-eye observations. When you come back with your binos, note the ragged outer loop of 8 or so bright stars that surround the boxy core of M34. And take a close look at 12 Persei — with a separation of 270″, it's a nice binocular double even at 7×.

Until now I've been using **Algol** (Stop 6) simply as a pointer, but it's time to give the Demon Star its due. If you've never watched this eclipsing binary do its dimming trick, it's well worth looking up the timings of the upcoming minima (see p. 50). It's remarkable how different the constellation looks with its second-brightest star knocked down to about a third of its normal brightness.

Riding the southern edge of the Milky Way is the open cluster **NGC 1342** (Stop 7), which forms a squat isosceles triangle with Algol and Epsilon (ε) Persei, lying almost exactly 5° from both stars. In any other part of the sky, NGC 1342 would probably be considered a showpiece object. Don't let its brighter neighbors turn you off the subtle charms of this pretty, easy-to-find cluster. See if you can detect a bright tri-




▲ **ROMAN CHARIOTEER** Using your binoculars, see if you can spot "the Waves" and the other clusters during the long January nights.

angular core inside a rough box of bright boundary stars.

Returning to Alpha Persei one last time, follow the tightening spiral of Delta (δ), 48, Mu (μ), and b Persei to the constellation's eastern "hand", which holds a challenging cluster of clusters. **NGC 1528** (Stop 8) is the easiest to find, 1° northwest of b Persei, and it's bright and isolated so you'll definitely see it. **NGC 1545** is trickier — at magnitude 6.2 it's technically a hair brighter even than NGC 1528, but its diffuse light tends to be overwhelmed by a 7th-magnitude foreground star.

For an even greater challenge, follow a lovely trail of stars southwest of NGC 1528 and see if you can spot 8th-magnitude **NGC 1513**. The two clusters form the diagonal corners of a rectangle with the stars b and Lambda (λ) Persei. NGC 1513 is both small and distant, and catching it in anything other than big, mounted binos requires clear, dark skies and excellent dark adaptation. Good hunting!

From Lambda Persei, shoot southeast past Mu Persei and 53 Persei to find **NGC 1582** (Stop 9). Big and sparse, this open cluster is more recognizable as a distinct object at low power. If your binoculars resolve the cluster, look for two curving arcs of stars, like a loosely wound barred spiral galaxy.

Less than 1° south of NGC 1582 lies **m Persei** (57 Persei), a great multiple star for small binoculars. The close pair form a true binary system, and with a separation of 121″ they are nicely split even at 7×. That binary pair forms a wide optical double, only coincidentally aligned, with 7th-magnitude HD 28782, which lies 442″ almost due east.

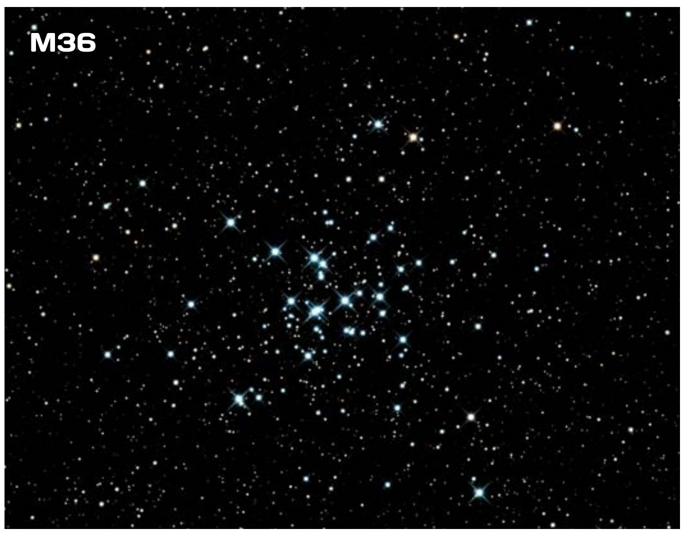
As long as you're scanning eastward, go 3° farther to find the open cluster **NGC 1664** (Stop 10 on the map on p. 65), approximately halfway between 59 Persei and Epsilon Aurigae. This small cluster is somewhat challenging — several foreground stars on its southern border are brighter. Magnification, patience, and averted vision should allow you to separate the cluster from its neighbors.

Epsilon Aurigae forms a long, narrow triangle with Eta and Zeta (ζ) Aurigae. Four degrees south of Eta and Zeta you'll find **NGC 1778** (Stop 11). Like NGC 1664, NGC 1778 is a small open cluster, barely more than 10 light-years in diameter. And it lies even farther away, 4,800 light-years from Earth, versus 3,900 light-years for NGC 1664. In 7×50 binoculars all I see is a tiny wisp of light. The cluster starts to resolve in 15×70s, which show its brighter stars in the shape of a check mark.

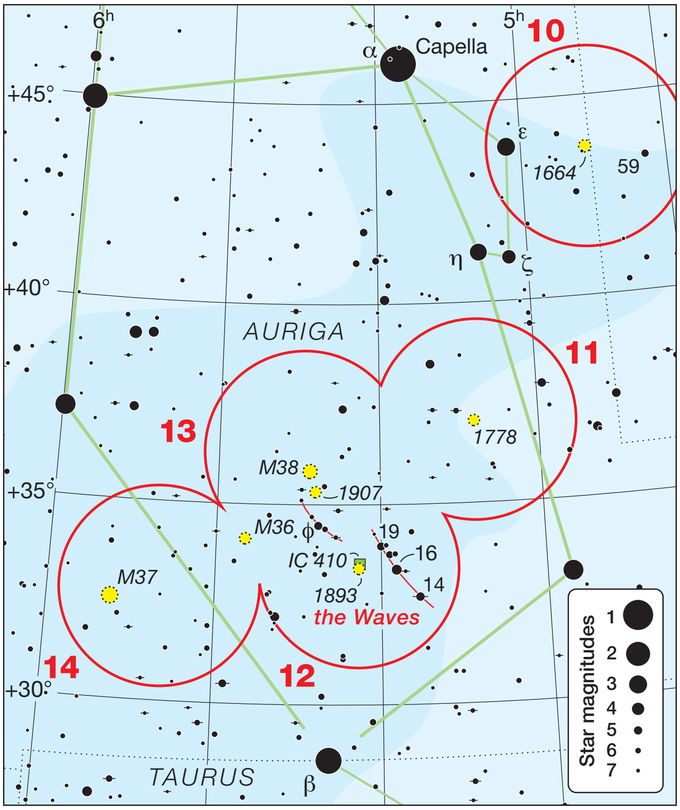
My guideposts to central Auriga are a couple of gently curving chains of stars that I call **the Waves** (Stops 12 and 13). The western one is longer and brighter and includes several 4th- and 5th-magnitude stars, particularly 14, 16, and 19 Aurigae. The smaller eastern wave, which lies northeast of its sister, includes 5th-magnitude Phi (φ) Aurigae but is otherwise made up of nameless 6th- and 7th-magnitude stars. The Waves are naked-eye visible under reasonably dark skies, and they point the way to celestial treasures.

Just off the southern end of the eastern wave is the open cluster **NGC 1893** (Stop 12), a challenging object, but worthy of careful study. The average distance to Messier and Caldwell

▼ **THE BIG, THE BRIGHT, AND THE BEAUTIFUL** M36, M37, and M38 are three open clusters that sparkle in Auriga. M37 is the brightest of the three, while M38 is the biggest. But they are all beautiful specimens of their class of object.




TOP: AKIRA FUJII; BOTTOM: ANTHONY AYIOMAMITIS




open clusters is just over 3,000 light-years, but we gaze at NGC 1893 across an astonishing 11,000 light-years. Even at that distance, it subtends nearly ½°, corresponding to an actual diameter of more than 80 light-years — this seeming minnow is actually a distant leviathan. The cluster is embedded in the faint nebula IC 410, from which it formed only four million years ago. I've never spotted the nebula myself, but 15× will resolve a ragged line of stars aligned almost perfectly north-to-south, aimed between the two Waves.

Just off the northern end of the smaller wave you'll find M38. Pause for a moment, though, and have a look at **NGC 1907** (Stop 13), ½° to the south. Comparing the two open clusters is instructive — NGC 1907 is both smaller in diameter and about a third again as distant as its brighter and more famous neighbor. Like many of the non-Messier clusters on this tour, it's just a fuzzy ball of fluff at 7×, but it starts to resolve at 15×.

Comparing clusters is the name of the game in the next stretch of the tour: We've arrived at the Messier trio of **M38**, **M36**, and **M37** (Stops 13 and 14). M36 is 2° southeast of M38, and M37 is just over 3° east-southeast of M36. All told the three span just over 5°, so they'll fit into the field of view of most 7×50 and 10×50 binoculars. With the smaller field of 15×70s you'll have to pick two clusters at a time to observe and compare.

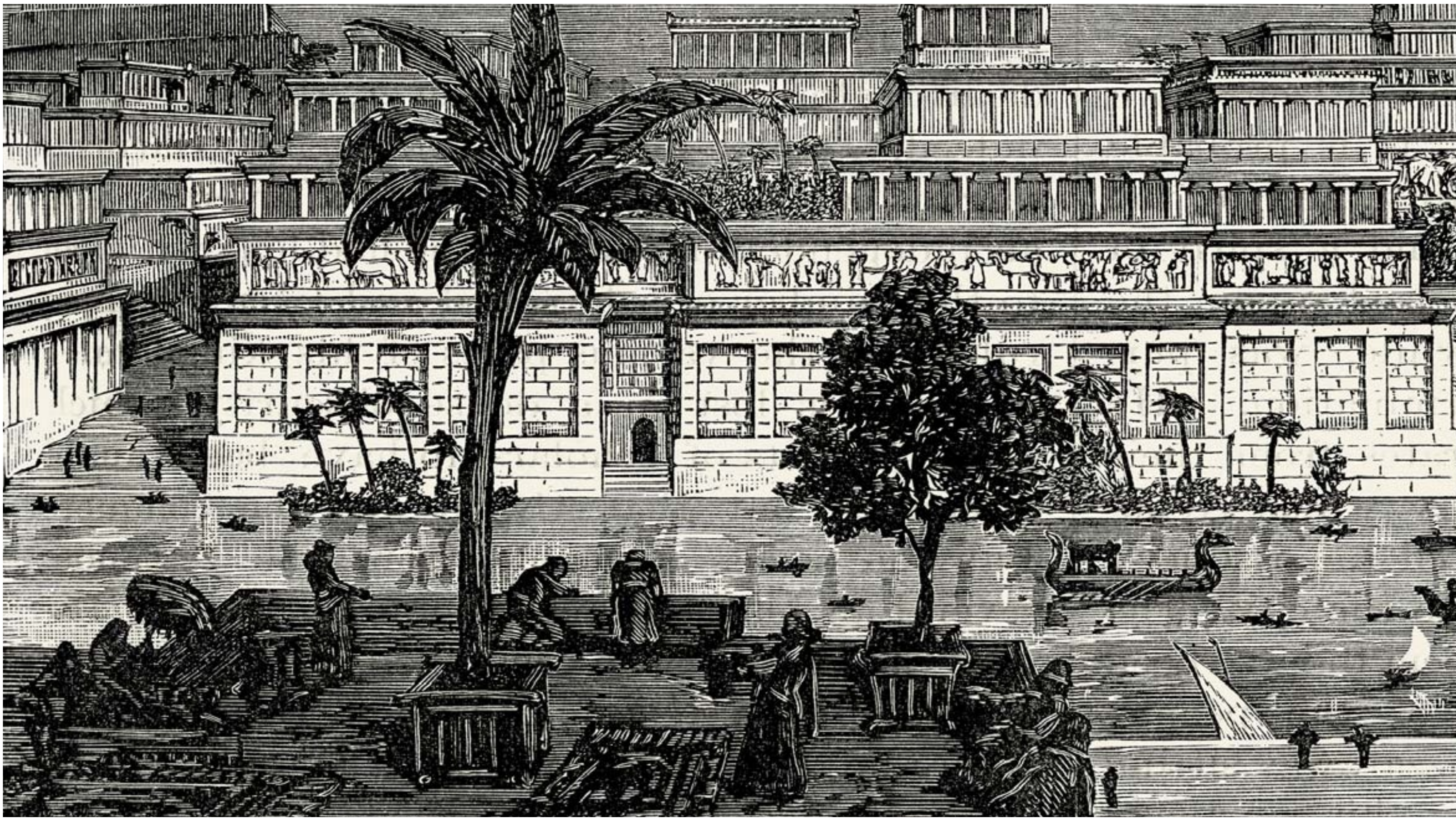
All three clusters lie at roughly the same distance from us, between 4,300 and 4,600 light-years away, so the differences you see mostly correspond to astrophysical reality. M38 looks the largest, and it is — its diameter is about 26 light-years, compared to 12 for M36 and 18 for M37. M36 has the fewest stars, but it is the flashiest of the three, a compact shotgun blast of brilliant blue-white stars. M37 is by far the richest, with hundreds of suns compared to the dozens in the other two clusters. Although technically intermediate in size between the other two, it often looks the smallest — the cluster's diffuse outer members are hard to detect in handheld binoculars, and what registers as "the cluster" in small instruments is in fact its dense core, only about 5′ across.

I called this a tour, but it's been more of a blitz, hitting a few showpiece objects but rocketing past many more. Perseus and Auriga will reward further exploration, whether you seek to understand the structure of our galaxy, or just relax and appreciate the beauty of the night sky. Don't take my word for it — go see for yourself.

■ Contributing Editor **MATT WEDEL** is frankly a little alarmed about trying to understand the night sky in a single lifetime. But he's enjoying the attempt.



CHART: GREGG DINDERMAN / *S&T*, SOURCE: *SKY & TELESCOPE'S POCKET SKY ATLAS*; M37 & M38: ANTHONY AYIOMAMITIS (2)



# The Ancient Circle of Animals

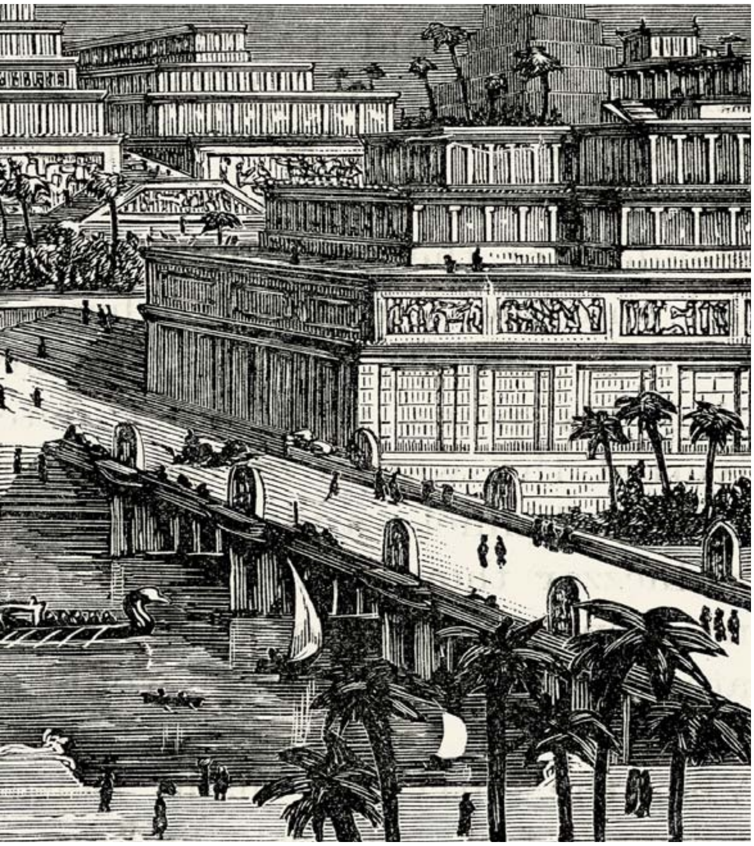
## The Moon travels among 12 lively constellations.

During the course of a year, the path of the Sun among the stars — the *ecliptic* — passes through 12 ancient constellations. Because all but one of these 12 constellations represent living things, human or animal, the Greeks called them the "Circle of Animals" — in ancient Greek, *kyklos zodiakos*, now shortened to *zodiac*. The one star pattern in the zodiac that doesn't represent an animal is Libra, the Scales. However, the Greeks considered the stars of Libra to be both a Scales and the Claws of the Scorpion, which follows Libra in the zodiac, so it's appropriate to include it in the circle as well.

The Greeks inherited the 12 constellations of the zodiac, as well as the concept of the zodiac as a singular object, from the Babylonians. (Ancient Babylonia occupied south-central Mesopotamia on the floodplain between the Tigris and Euphrates Rivers; today, it corresponds to southern Iraq.) The concept of the zodiac was closely related to horoscope astrology — the system of predicting a person's character and future from where the Sun and planets were in the zodiac at the time of their birth — a practice which also came to Greece from Babylonia, though it was a very late development in Mesopotamia. In fact, the earliest known horoscope from Babylonia dates only to 410 BC. But by that time Babylonia had been under the rule of Persian kings for over a century. The ancient Persians were Sun-worshippers, whereas traditionally the Babylonians had used a lunar rather than a solar calendar. Thus, though it was indeed the Babylonians who conceived of the 12 ancient constellations in the path of the Sun as a unit, which the Greeks then called the zodiac, they did so only as late as the 5th century BC under the influence of Persian Sun-worship.

▲ **ANCIENT ART** Mesopotamian astronomy dates to the First Babylonian Dynasty (c. 1894–1595 BC), but it continued to develop through the Selucid Empire (c. 323–60 BC).

BABYLON: DUNCAN1890 / ISTOCK / GETTY IMAGES PLUS; ANIMALS: HEVELIUS



Horoscope astrology as we think of it today developed even later: It didn't attain its final form and great popularity until the 3rd century AD, when the social and political dislocations of the decaying Roman Empire made the powerless multitudes vulnerable to any superstition that promised knowledge about the insecure future and some illusion of control over it.

## Lunar versus Solar Calendars

The First Babylonian Dynasty was founded in 1894 BC, but the calculation of lunar calendars dates to even further back. The Sumerians, the cultural predecessors of the Babylonians in southern Mesopotamia, are usually credited with the development of a calendar based on lunar months. The precedence of a lunar over a solar calendar is logical: The path the Moon follows among the stars is much easier to observe than the path of the Sun. The downside of a lunar calendar is evident, however. There isn't an integral number of lunar months in a solar year — it comes out to about 12 and a half — so it's necessary to add an occasional intercalary lunar month to keep a lunar calendar in synch with the meteorological seasons.

The Sumero-Babylonian New Year began with the first visible evening crescent Moon following vernal equinox (when the Sun crosses the plane of Earth's equator, south to north) and therefore usually fell in what corresponds to our late March/early April. Month names, keyed to the lunar calendar, appear on Sumerian clay tablets written before 3000 BC. But most of the Sumerian month names known to us relate to religious festivals that took place during those months: None refer explicitly to any constellation on the ecliptic.

## The Babylonian "Lunar Zodiac"

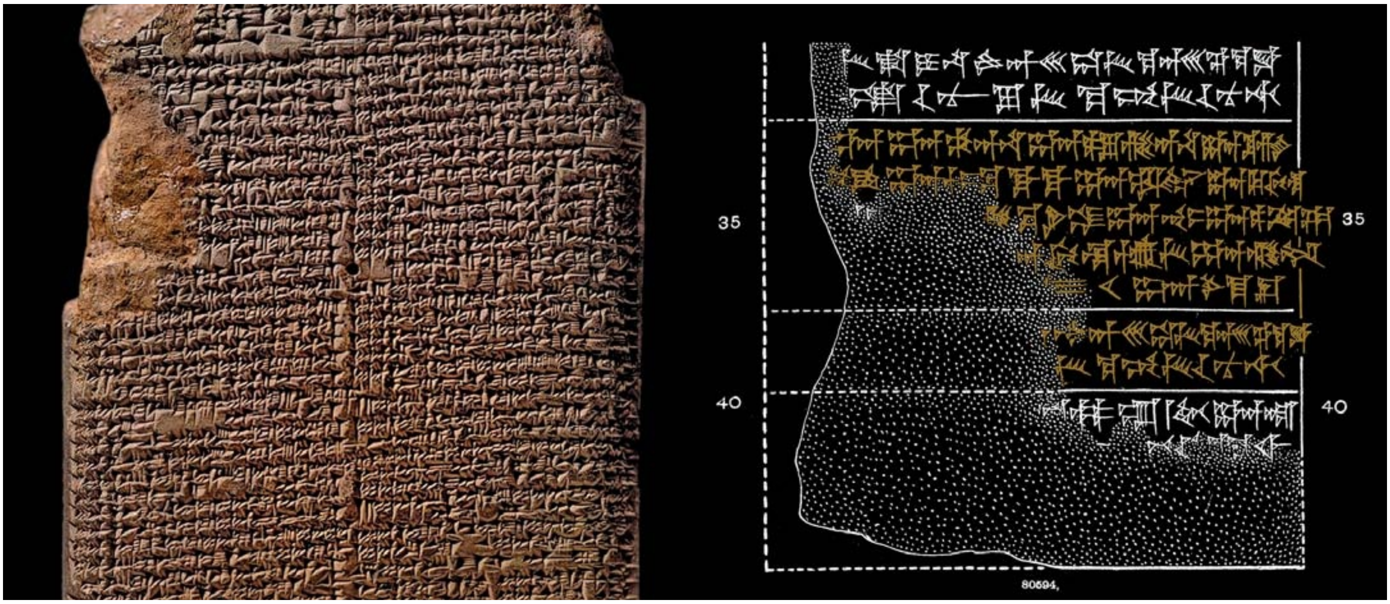
The oldest, complete, surviving astronomical work is a 2-tablet compilation titled (by the ancients themselves, after its first words) *MUL.APIN*, meaning "Constellation of the Plow." Several copies of it — broken, but almost fully restorable — were found in the mid-19th century in the ruins of the palace at Nineveh of the Assyrian king Ashurbanipal (r. 668–627 BC). These tablets were written in the early 7th century BC, but internal evidence suggests that the text itself was actually composed before 1000 BC.

### Sumero-Babylonian Constellations "In the Path of the Moon"

| Name | Translation | Identification |
|---|---|---|
| MUL.MUL | The Constellation *par excellence* | Pleiades |
| Gu$_4$-an-na | Bull of Heaven | Taurus |
| Sipa-zi-an-na | Steadfast Shepherd of Heaven | Orion |
| Šu-gi | Old Man, Wizard | Perseus |
| Gàm | Scimitar, Wizard's Wand | Perseus Double Cluster |
| Maš-tab-ba gal-gal | Great Twins | Gemini |
| AL-LUL | Crab | Cancer |
| UR-GUL-LA | Lion | Leo |
| Ab-sín | Ear of Grain | Spica |
| *Zibānītum* | Scales | Libra |
| Gír-tab | Scorpion | Scorpius |
| Pa-bil-sag | [an archaic war-god] | Sagittarius |
| Šuhur-maš$^{ku6}$ | Goat-Fish | Capricornus |
| MUL.GU-LA | The Great Constellation | Aquarius |
| Kun$^{meš}$ | Tail (of the Fishes) | Pisces |
| Ším-mah | Great Swallow | Circlet of Pisces |
| *Anunītum* | [the goddess Ishtar] | Northern Fish & Beta (β) And |
| $^{lú}$Hun-gá | Hired Laborer, Plowman | Head of Aries |

These entries come from the *MUL.APIN*, Tablet 1, column iv, lines 33-57. The transcriptions in the left column follow standard Assyriological practice for transcribing the original cuneiform.

LION: HEVELIUS

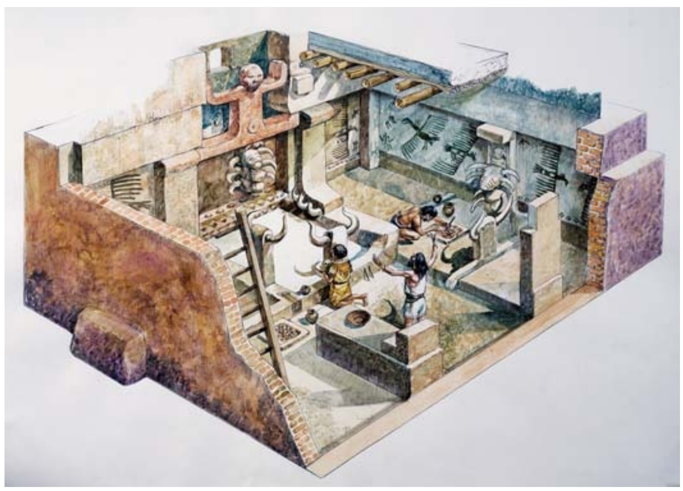



▲ **ANCIENT ASTRONOMICAL TEXT Left:** Unearthed from the ruins of an Assyrian palace in southern Iraq, this clay tablet, composed in the Akkadian language and inscribed in cuneiform, displays the opening lines of *MUL.APIN*. The full text of *MUL.APIN*, known from several larger tablets, contains a wealth of astronomical information, including the names of the major stars and constellations; the heliacal rising dates of important stars; lists of stars and constellations that rise, culminate, or set at the same time; and methods for determining the positions and movements of the Sun, Moon, and planets. **Right:** Egyptologist E. A. Wallis Budge of the British Museum published this transcription of the reverse side of the *MUL.APIN* tablet in 1912. Though broken, enough of this and other tablets remain to allow archaeologists like Budge to decipher the names of the important stars "In the Path of the Moon." The relevant section is highlighted on the transcription above.

Given the importance of the lunar calendar to the ancient Mesopotamians, it isn't surprising that *MUL.APIN* doesn't itemize the stars and constellations along the path of the Sun, but rather catalogs those "In the Path of the Moon" (see the table on page 67). This list includes 18 stars and star-groups, or six more than we find in the modern solar zodiac, and none are associated with specific, individual months. Virtually all of the 12 Graeco-Roman zodiacal constellations appear in this catalog in some form, seven explicitly so. Two of the star groups, *Pa-bil-sag* and *GU-LA*, served as prototypes for the classical conceptions: Pa-bil-sag was envisioned as an Archer-Centaur and GU-LA as a Water-Pourer holding a Streaming Water-Jar. It would seem, then, that the Graeco-Roman 12-constellation solar zodiac resulted from a process of selection from this Mesopotamian ur-catalog of an 18-constellation lunar zodiac. That winnowing, as mentioned above, was done by Babylonian astronomers and astrologers during the 5th century BC, when Babylonia was under control of the Sun-worshipping Persians.

## Earliest Ecliptic Constellations

The antiquity of the list of constellations "In the Path of the Moon" is indicated by its lead star-group, *MUL.MUL*, the Greek Pleiades. At the time the surviving tablets of *MUL.APIN* were inscribed, around 700 BC, the vernal equinox was in the middle of the classical constellation of Aries. Given the importance of the vernal equinox for the Mesopotamian lunar calendar, had the constellation list actually been compiled around the time it was inscribed, it undoubtedly would have started with $^{\text{lú}}$*Hun-gá*, predecessor of the modern constellation Aries. The Pleiades were just west-northwest of the vernal equinox during the 3rd millennium BC and would have risen in the morning twilight around the time of the equinox. That they head the list suggests that it was first compiled in the 3rd millennium BC. This is consistent with the fact that the vast majority of the list's star and constellation names are in Sume-



▲ **NEOLITHIC CATTLE** The settlement of Çatal Hüyük, which dates to c. 7500–5700 BC, consisted of rectangular mud-brick houses, arranged such that access was available only through roof openings. Inside many of these single-story dwellings were rooms ornamented with colorful pigments, animal heads, bucrania (bovine skulls), and horns embedded in stylized bulls' heads or attached to benches and pillars.

rian, which ceased to be a living language soon after 2000 BC.

The most ancient zodiac constellations are probably the Bull, the Lion, and the Scorpion. Neolithic art and religious iconography are rich in images of those creatures, though it's difficult to discern which of these, if any, were meant to be explicitly astronomical. In any case, the star patterns of Taurus and Scorpius are sufficiently similar to actual bulls' heads and scorpions that it is a safe bet that those constellations were conceived of during the Neolithic. Around 7000 BC, numerous bulls'-heads and bulls'-horns were sculpted of clay plaster on walls and benches (altars?) in what seem to have been ceremonial rooms in the Neolithic town excavated at Çatal Hüyük in modern southern Turkey. Whether or not these objects were thought to have astronomical relevance is impossible to say; but such a culture would have had a natural inclination to see the star pattern of our Taurus as representing a bull's head.

▲ **EVOLVING TWINS** This seal impression shows the enthroned water god Enki receiving his double-faced vizier, Isimud. The pair is flanked by the Twin Gatepost-Holders, the prototype(s) of Gemini. Enki holds his Streaming Water-Jar, which eventually would evolve into Aquarius.

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## The Northern Zodiac

The presence in *MUL.APIN* of *Sipa-zi-an-na* (Orion) and *Šu-gi* (Perseus), groups that are not on the ecliptic, is at first sight something of a puzzle. However, the Moon's path among the stars is inclined 5° to the Sun's path, so the Moon sometimes does approach southern Perseus and northern Orion. The Sumerian prototypes of Perseus and his Scimitar — a wizard with his curved wand — are described in a previous article (*S&T:* May 2016, p. 24).

Though it's a northern constellation, *Maš-tab-ba gal-gal*, the Great Twins (Gemini), was associated with the patron deity of the southern skies, Enki, the water-god of the archaic Sumerian city of Eridu. This association might hearken back to the early 4th millennium BC, when Eridu was the cultural center of Mesopotamia, and its patron deity presumably held sway over most of the heavens. The Great Twins were envisioned as the Gatepost-Holders of Enki and shown as such on numerous cylinder seals carved during the 3rd millennium BC. These seals display the god enthroned, holding his sacred Streaming Water-Jar, flanked by two nude, wild-haired, frontally faced figures grasping buckled gateposts.

The same kind of nude, wild-haired figure is shown on other cylinder seal designs that include Enki's Streaming Water-Jar and was the prototype of the classical Aquarius. Later Mesopotamian texts recommended that terracotta plaques of these Gatepost-Holders, which they called *talim* ("Twins"), be buried in the corners of courtyards as protection against evil influences and demonic intruders.

## Virgo and Her Ear of Grain

As its appearance on the "In the Path of the Moon" list suggests, the celestial Ear of Grain, the classical Spica, also has Mesopotamian roots. The original meaning of the Sumerian word *ab-sín* was "furrow": The Sumerians thought of the ecliptic as a celestial plow-furrow and our Alpha Virginis as a seed-grain planted in in it. Planting scenes, some of them clearly astronomical, were quite frequent in Mesopotamian cylinder seal designs of the mid-3rd millennium BC, so it's reasonably certain that the celestial Ear of Grain was in the sky by that time.

Though not explicitly included in the table of constellations "In the Path of the Moon," other sections of *MUL.APIN* refer to a celestial "Great Lady," *Nin-mah*, and locate her in the same area of the sky as the Ear of Grain. Nin-mah was one of the Sumerian epithets for the famous fertility goddess Ishtar (Sumerian Inanna), forerunner of the Greek Aphrodite. Thus the constellation Nin-mah was almost certainly the predecessor of the classical Virgo.

As a fertility goddess, Nin-mah was accompanied in the sky by two of her icons: the Ear of Grain, represented by Alpha Virginis; and a Date Cluster represented by the Coma Berenices Star Cluster. A mid-3rd millennium BC cylinder seal design shows a winged Inanna/Ishtar holding her Date Cluster and standing on a mountain range from behind which the sun-god Utu is rising. To the right is Enki, patron deity of the southern heavens, holding Corvus, the celestial Raven, in one hand; and to the left is Leo, the Lion (the constellation west of Coma Berenices), as well as Enlil, patron god of the northern skies. This cylinder seal design shows the heavens as they would have appeared in the third millennium BC at sunrise in early September, the time of year the highly important date harvest began.

By the time the "rising Sun" cylinder seal was carved, the balance-beam Scales that would become Libra were also in the sky. The remains of such scales have been found during excavations at Sumero-Babylonian sites, and at least three mid-3rd millennium seal designs are known which show a balance-beam scale with trays. One of these designs depicts the scale being held over an altar in front of the enthroned Sun-god, Utu. This could be interpreted as a reference to the Sumerian god of Justice, Utu (Akkadian Shamash).

## The Archaic Archer

The deity name Pa-bil-sag, which *MUL.APIN* applies to the stars of the classical Sagittarius, was a throwback. During the early 3rd millennium BC, Pa-bil-sag was the war-god of the

**MORNING HARVEST** This impression, made from a seal dating to c. 2300 BC, shows a winged Ishtar/Inanna holding her date cluster (Coma Berenices) over the rising Sun-god, Utu. The water-god Enki, his Streams replete with fish, steps over a crouched Bull. A Raven (Corvus) perches on Enki's hand. To Enki's right stands the two-faced vizier, Isimud. At left, a Lion (Leo) roars at a figure carrying a bow (possibly the war-god Ninurta). This seal illustrates the heavens just before sunrise at the time of the southern-Mesopotamian date harvest during the 3rd millennium BC.

archaic Sumerian city of Larak. But by the end of the millennium he'd been absorbed by Ninurta, the war-god of the great Sumerian religious capital of Nippur, sacred city of Enlil, and the paramount deity of the Sumerian pantheon. Thus the title Pa-bil-sag for the stars of Sagittarius can be read as a residual of early 3rd millennium BC Sumerian astro-nomenclature.

It is, however, doubtful that Pa-bil-sag was originally envisioned as an archer-centaur: Centaurs do not appear in Mesopotamian art until the late 2nd millennium BC, and centaur-archers even later. However, there's absolutely no doubt that the classical Sagittarius figure did originate in Mesopotamia, because the archer-centaurs that appear on the Egyptian zodiacs carved in the temples at Dendera and Esna on the Nile during the final two centuries BC under Hellenistic Greek influence are exactly the same as archer-centaurs that appeared on Neo-Assyrian cylinder seals around 800 BC.

## The "Watery" Zodiac

I described the origins of the "watery" constellations of the zodiac — Capricornus, Aquarius, and Pisces — in a previous article (*S&T:* March 2015, p. 36). Briefly, the celestial Goat-Fish seems to have been invented around 2100 BC as the descendant of a celestial goat-prowed Boat that had previously occupied these stars; and the Water-Jar and Streams of Aquarius probably go back at least to the early 4th millennium BC as they were the special icons of Enki, whose city Eridu was the cultural center of Mesopotamia at that time. In any case, the Water-Pourer figure appears on Mesopotamian cylinder seals as early as 2300 BC. Pisces, however, was likely a late addition to the "watery" part of the Mesopotamian heavens because 1) there's no clear mention of celestial "Fishes" in the texts of the 2nd millennium BC; 2) even a name like *MUL.APIN*'s *Kun*$^{meš}$ ("Tails"), is indirect; and 3) at least one part of the classical Pisces, the asterism of the Circlet, had a separate name in Sumerian — *Ším-mah* ("Great Swallow"), which goes back to the 3rd millennium BC. Taken together, these facts suggest that the zodiacal Fishes were an afterthought inspired by the presence of the more ancient "watery" constellations near it.

**HALF HORSE WARRIOR** The archer-centaur, a familiar concept in Mesopotamian art, was associated with the Sumerian deity Pa-bil-sag, whose name was given to the star pattern that became Sagittarius. The Greek-influenced archer-centaurs that appear on the Egyptian zodiacs in the temples at Dendera, such as the one circled above, are identical to those found on Neo-Assyrian cylinder seals engraved c. 800 BC.

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**BULL WITH SEVEN SISTERS** Probably carved around 800 BC, this Neo-Assyrian seal made explicit the connections between agriculture and the heavens for Mesopotamian cultures. Here, a plowman drives a single beast to make a furrow. Above the Bull shine the Sun, Moon, and Pleiades. In front is the Ear of Grain, the Roman Spica.

SEAL: W. H. WARD, *THE SEAL CYLINDERS OF WESTERN ASIA* (CARNEGIE INSTITUTE, 1910); RAM: HEVELIUS

## The Origin of the Ram

Finally, there's the problem of Aries, the Ram, the one constellation of the Graeco-Roman zodiac that doesn't have an obvious Sumero-Babylonian forerunner. *MUL.APIN* calls these stars (probably referring particularly to the asterism of Alpha-Beta-Gamma Arietis) $^{\text{lú}}$Hun-gá, "Hired Laborer." This may be taken to mean "Plowman," because the Mesopotamians figured a celestial Plow occupying the stars of our Triangulum plus Gamma Andromedae just to the north of this figure. This Plow was pulled by the Bull (Taurus) just to its east to cut the Furrow of the heavens (the ecliptic), with the Plowman guiding it. That scene is shown on a Neo-Assyrian cylinder seal of about 800 BC. The seal's design also shows the Pleiades in their correct position above the Bull's back, and the Ear of Grain — our Spica — directly in front of the Bull.

But all this doesn't explain why the Greeks had a Ram in the stretch of the zodiac where the Mesopotamians earlier had a Plowman. However, *MUL.APIN* itself provides a possible explanation: It identifies the celestial Hired Laborer with the shepherd-god Dumuzi. Accepting this interpretation of the Hired Laborer as the shepherd-god Dumuzi, the Greek zodiacal Ram can be read as the Leader of the Flock of Dumuzi.

This identification of Dumuzi with the stars of the Plowman isn't as arbitrary as it might seem: Preceding Dumuzi ($^{\text{lú}}$Hun-gá) "In the Path of the Moon" is *Anunītum*, an epithet for the fertility goddess Inanna/Ishtar, spouse of Dumuzi, who therefore occupied the stars of the Northern Fish of Pisces. Moreover, the association of the stars of the Northern Fish with Inanna/Ishtar was no accident, because the part of the zodiac that stands 180° from Virgo is Nin-mah, which, it will be recalled, was another epithet for Inanna/Ishtar (as other tables in *MUL.APIN* show, the Mesopotamians were very alert to which constellations rose and set opposite each other).

The association of the stars of Pisces with Inanna/Ishtar, prototype of the Greek Aphrodite and Roman Venus, was remembered in Graeco-Roman astrology because Pisces was the hypsomata, "House," of the planet Venus. Moreover, both classical astro-mythographers Hyginus and Manilius relate the story that Venus and Cupid, when confronted on the banks of the Euphrates (the very venue of the story suggests a Mesopotamian origin!) by the monster Typhon, escaped by diving into the river and changing into a pair of fish, the zodiacal Pisces.

## The Cycle of Animals

So how and when did the constellations of the zodiac come from Mesopotamia to Greece? The "how" is easier to answer than the "when." For thousands of years, trade had been going from southern Mesopotamia up the Tigris and Euphrates rivers north into southeastern Anatolia (modern Turkey) and west to Syria and the Mediterranean. From Syria, the trade went south to Egypt and west to the Greek islands. This trade carried not only goods but also the culture of the Sumerians and Babylonians. A fragmentary list of Mesopotamian star and constellation names that dates to roughly 1375 BC was found at Tell el-Amarna in central Egypt. But the Mesopotamian constellations were probably known in Egypt long before this, because features of Sumerian culture — particularly in art and architecture — appeared in Egypt before 3000 BC and presumably the Sumerian constellations had come with them.

Constellation figures are easier to follow on their march from Babylonia to Greece than constellation names because most of the traders and travellers were not literate. Thus the constellation figures can be thought of as tracers of the flow of civilization in ancient times. For example, the image of the Mesopotamian Water-Pourer appears in the early 2nd millennium BC in the art of both southeastern Anatolia and Syria. By the mid-2nd millennium Babylonian star-figures like the Water-Pourer, the Goat-Fish, the Serpent-Wrestler, and the Dragon-Drawn Wagon had become part of general Eastern Mediterranean culture. Therefore they were part of the fabric from which the Greek poets of the early 1st millennium BC wove their myths and epics.

■ **CRAIG CROSSEN** is a freelance writer, editor, and traveler who calls Minnesota home base. He co-authored *Sky Vistas* (2004) and has published several articles on the structure of the Milky Way Galaxy in *Sky & Telescope* and elsewhere. Presently he is completing books on the origins of the Classical constellations and on the history of archaeology in Iraq.

# A New Criterion

*Larry Myers raises the bar on rebuilds.*

**IN OCTOBER AND NOVEMBER** of last year, I wrote about telescope design many years ago and what's possible now. This month we see a marriage of the two in the rebuilding of an old, 8-inch Criterion reflector.

The scope dates back to about 1963. It came to Oregon ATM Larry Myers as a wedding gift in 2002, but aside from a few outings and despite relatively good optics, it mostly sat in storage. Then, as Larry says, "Fast forward 15 years and plus one son." Now 10 years old, Logan has a real propensity for science. So Larry decided he would fix up the old Criterion for his birthday.

"In retrospect," Larry says, "I'm glad I started many months prior to his birthday. Taking a closer look at the mount, I saw that the declination axis was in need of repair. The bushings were trashed and the shaft was badly rusted." Even the castings were shot. So right off the bat, Larry had to make a whole new declination assembly. Then a little more digging showed that the right ascension axis was just as bad. So what the heck, he would rebuild the entire mount.

That wasn't as much of a problem for Larry as it might be for most of us, since he runs a CNC machine shop. Using mostly materials already on hand, he designed and built the mount you see here. He included optical encoders and a tracking motor, but decided to make the scope a Push To rather than a Go To. Why? "I wanted my son to learn the sky as opposed to him just pushing buttons."

But it wasn't just the mount in need of repair. The original pier and legs were pretty flimsy, so Larry replaced those, too. Eschewing the original aluminum castings, he designed some hardwood (cherry) legs, which he laminated cross-grain for strength. One benefit of the wood besides merely being pretty: The system dampens vibration much more quickly than the metal legs did.

Larry used a piece of 6-inch well casing for the pier and had it powder-coated a dark bronze, which contrasts well with the brass knobs and other fittings.

Rotating tube rings completed the mount. That left the OTA, which was, in Larry's words, "Fairly well made and well beaten. I re-fiberglassed, filled, scraped, sanded, messed up, and redid the whole thing." Eventually he repaired it to his satisfaction and sent it out to be Cerakoted, a durable thin-film ceramic coating used in firearms. It returned looking brand-new again.

The scope had come with a 1¼-inch Meade rack and pinion focuser, which Larry cleaned up and kept, although he plans to replace it eventually with a 2-inch Crayford. He kept the primary mirror (which had been replaced with a Cave optic before the scope was given to Larry) and the secondary mirror, as well as the primary cell and secondary spider assembly. He then added adjustable weights fore and aft to help with balance.

He replaced the original finder with a Telrad and then topped it all off by adding his old Celestron Comet Catcher that he had restored several years earlier. That's a 5.5-inch f/3.6 Schmidt-Newtonian — and a pretty hot scope in its own right. It may be overkill as a finder, but you have to admit it looks awesome perched up there on top of the finished Criterion.

First light was, in Larry's words, "Dismal. I had miscalculated the focal distance. We could not achieve focus.

Larry, Logan, and Zupa Myers pose with the beautifully restored 8-inch Criterion.

LARRY MYERS

▲ **Top:** The telescope's new mount includes a motor drive, brass fittings, and digital setting circles. **Bottom:** This is one of the two adjustable counterweights added to aid balancing the optical tube assembly.

LARRY MYERS (2)

Fortunately I had set up the OTA prior to doing the finish surface on it. I was able to drill new cell holes into the tube and re-fiberglass and finish/hide my original holes. Once mended, the optics performed perfectly!"

Larry reports, "I was able to complete about 99% of the scope prior to my son's birthday. Needless to say, Logan was pretty excited about his 'new' scope. I hope he still has it when I am long gone just to remember that his dad was a geeky telescope maker."

I have no doubt of that! This 60-year-old kid would keep it forever.

■ Contributing Editor **JERRY OLTION** used to share a 6-inch Criterion with his brother. He remembers the optics, but not the mount, fondly.

• **For more information, contact Larry at sales@colfaxtactical.com.**

△ SIGHTSEEING IN NORTH AMERICA

Joshua Rhoades

Telescopic observers wish the iconic North America Nebula (NGC 7000), 1,600 light-years away in Cygnus, looked as glorious visually as it does in color images.

**DETAILS:** *Stellarvue SV80 Access apochromatic refractor, modified Canon EOS T3i DSLR camera used at ISO 800. Total exposure: 1.5 hours.*

▷ THE CYGNUS WALL

Terry Hancock

Within the North America Nebula is a dense zigzag of interstellar gas and dust where stars are forming. This cosmic wall spans about 20 light-years.

**DETAILS:** *Takahashi FSQ-130ED apochromatic astrograph and QHY367C CMOS camera. Total exposure: 60 minutes.*

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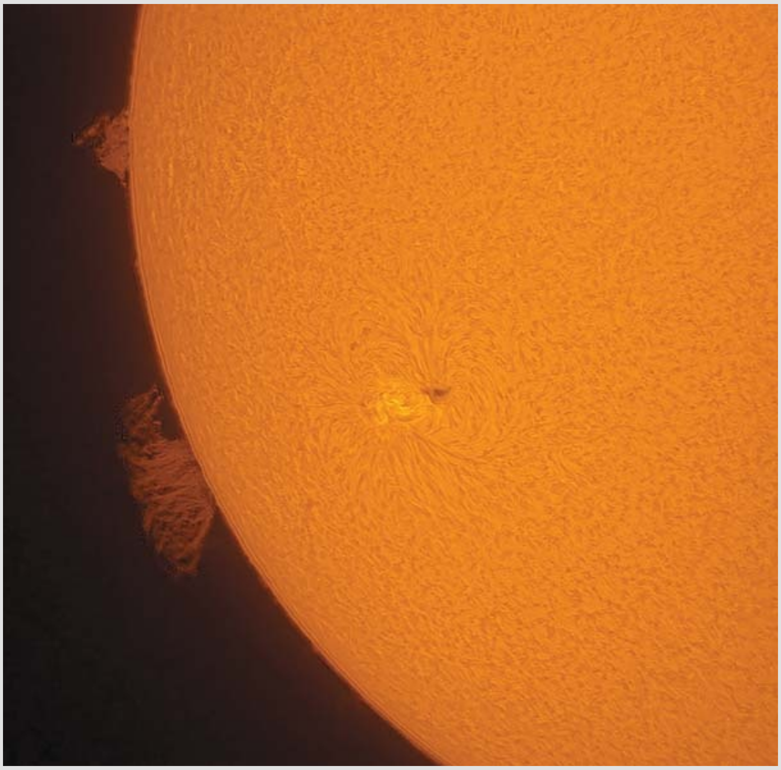

### ▷ SOLAR SIZZLE

Paco Bellido

During a month with record high temperatures across Spain, on July 8th the Sun sported a fan-shaped prominence that lifted 70,000 km above the photosphere. A smaller eruption sits above it.

**DETAILS:** *Coronado SolarMax II 60 hydrogen-alpha solar telescope and Imaging Source DMK 41AU02.AS CCD video camera. Stack of 3,000 images.*

### ▽ COLOSSAL LUNAR ECLIPSE

Gianluca Masi

On August 7th, two weeks before America's total solar eclipse, the geometry was reversed and the Moon glanced through Earth's umbra. Here it is seen rising over Rome's Colosseum at dusk.

**DETAILS:** *Canon EOS 7D Mark II DSLR camera at ISO 400 and a 100-to-400-mm zoom lens used at 153 mm. Exposure: 1⁄30 second.*

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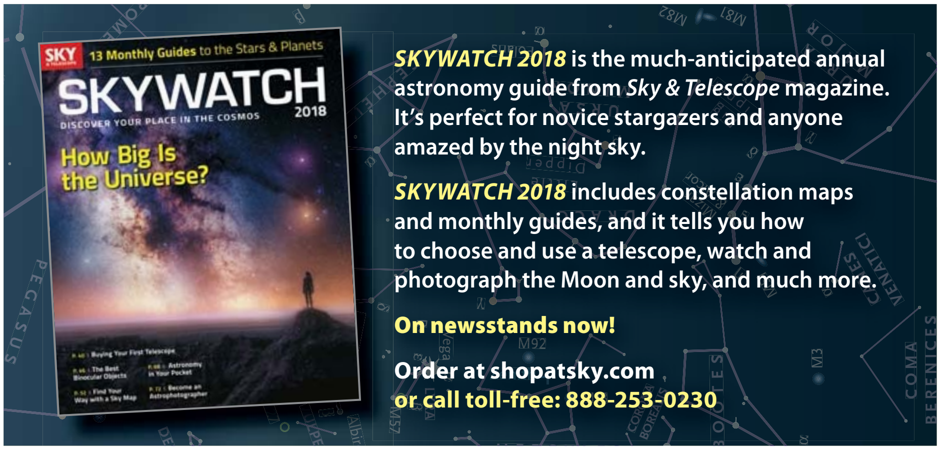
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Telescope.com
800-447-1001

**Sky-Watcher USA** (Page 8 & 9)
SkyWatcherUSA.com
310-803-5953

**Stellarvue®** (Page 73)
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530-823-7796

**Tele Vue Optics, Inc.** (Cover 2)
TeleVue.com
845-469-4551

## Dealer Locator

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**Orion Telescopes & Binoculars** (Page 3)
Telescope.com
800-447-1001

### CALIFORNIA

**Woodland Hills Telescopes** (Page 77)
Telescopes.net
888-427-8766 | 818-347-2270

*To advertise on this page, please contact Tim Allen at 773-551-0397, or Ads@skyandtelescope.com*

## AD INDEX



# Event Calendar

Here's the info you'll need to "save the date" for some of the top astronomical events in the coming months.

*February 12–18*
**WINTER STAR PARTY**
Location TBD (hurricane damage)
**scas.org/winter-star-party**

*April 21–22*
**NORTHEAST ASTRONOMY FORUM**
Suffern, NY
**rocklandastronomy.com/neaf.html**

*April 21 (also October 13)*
**ASTRONOMY DAY**
Everywhere!
**astroleague.org/al/astroday/astroday.html**

*May 6–13*
**TEXAS STAR PARTY**
Fort Davis, TX
**texasstarparty.org**

*May 24–28*
**RTMC ASTRONOMY EXPO**
Big Bear City, CA
**rtmcastronomyexpo.org**

*June 9–16*
**GRAND CANYON STAR PARTY**
Grand Canyon, AZ
**tucsonastronomy.org/upcoming-events/grand-canyon-star-party**

*June 13–17*
**ROCKY MOUNTAIN STAR STARE**
Gardner, CO
**rmss.org**

*June 14–17*
**CHERRY SPRINGS STAR PARTY**
Coudersport, PA
**astrohbg.org/CSSP**

*July 11–15*
**GOLDEN STATE STAR PARTY**
Bieber, CA
**goldenstatestarparty.org**

*August 5–10*
**NEBRASKA STAR PARTY**
Valentine, NE
**nebraskastarparty.org**

*August 7–11*
**TABLE MOUNTAIN STAR PARTY**
Oroville, WA
**tmspa.com**

*August 7–12*
**OREGON STAR PARTY**
Indian Trail Spring, OR
**oregonstarparty.org**

*August 9–12*
**STELLAFANE CONVENTION**
Springfield, VT
**stellafane.org/convention**

*August 9–12*
**STARFEST**
Ayton, ON
**nyaa.ca/starfest.html**

*September 7–11*
**ALMOST HEAVEN STAR PARTY**
Spruce Knob, WV
**ahsp.org**

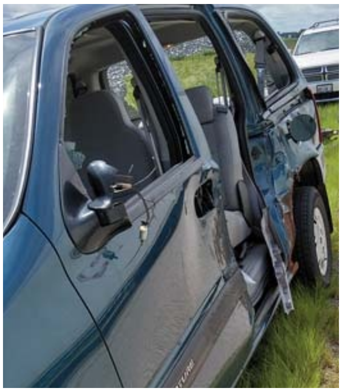
*October 6–14*
**OKIE-TEX STAR PARTY**
Kenton, OK
**okie-tex.com**

• For a more complete listing, visit https://is.gd/star_parties.

NPS / MICHAEL QUINN

# Wheel of Misfortune

*A freak accident after the August eclipse mars the author's memory of an otherwise sensational event.*




**THE GREAT AMERICAN ECLIPSE** was glorious (see page 14). But for me, the afterglow faded more quickly than I could have imagined.

I'd witnessed the last total solar eclipse to cross the continental U.S., in February 1979. For that event, I'd convinced my mom and dad to drive my younger brother and me to North Dakota, one of only four states the path of totality would cross. I'd completed my homebuilt 8-inch f/6 reflector just months before. The big Newtonian was too bulky to fit in my parents' sedan, so I had to settle for views of the corona through my 50mm Kmart refractor.

For the 2017 eclipse, though, my prized, handmade scope made the trip. My wife Laura and I had booked a hotel room in Festus, Missouri, a year in advance of the eclipse, and we drove there from Milwaukee for the event. The views through my old scope were spectacular, both with a custom-crafted filter during the partial phases and unfiltered during totality. That evening, I regaled my sister and brother-in-law with views of Saturn, M7, Albireo, and other celestial showpieces.

Little did I know it would prove to be "last light" for the venerable scope.

Laura and I had planned to continue our vacation for a few days, including an evening in Galena, Illinois, where we'd honeymooned three years before.

> Can an amateur astronomer mourn his lost telescope?

But it was not to be. On the interstate north of St. Louis, I caught a glimpse of a large object barreling toward us across the median. A split second later, a wheel from a southbound tractor-trailer rig slammed into the side of our Chevy minivan. The impact jolted the vehicle, but I regained control and pulled onto the shoulder.

Once we realized we were relatively uninjured, we turned around to survey the damage. The view out the driver's side of the van startled us — we saw mostly open air. Every window was gone; so was the sliding side door. We got out, shaking glass fragments from our hair and clothing.

When Laura opened the passenger-side sliding door, her heart sank. We'd carefully placed the optical tube across the second-row seats and secured the seatbelts around it. But the wheel's impact had shoved the telescope violently across the vehicle and into the opposite door. The resin-impregnated cardboard tube collapsed. The cast-aluminum primary mirror cell broke, the secondary mirror spider got severely bent, and all the external accessories, except the focuser, were sheared off the tube and damaged.

It's hard to walk past the spot in the house where I stored my scope without bemoaning its absence. Can an amateur astronomer mourn his lost telescope? I'm allowing myself to do so, but I'm also planning a rebuild.

If the heart of a reflector is its primary mirror, this telescope still has a faint pulse. Amazingly, no damage occurred to either mirror, other than barely scuffed coatings. And the Edmund Scientific equatorial mount was unscathed, as was the accessory case with its trove of eyepieces and filters. I will have the mirrors recoated, purchase a new tube, and build a new primary mirror cell and secondary mirror holder.

Almost 40 years on, I am once again an amateur telescope maker. With luck, the 8-inch scope will be ready for my next astronomy presentation at our local nature center.

■ **JIM HAHN** is a software engineer in Milwaukee, Wisconsin.

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# 2018 30°s Skygazer's Almanac

FOR LATITUDES NEAR 30° SOUTH

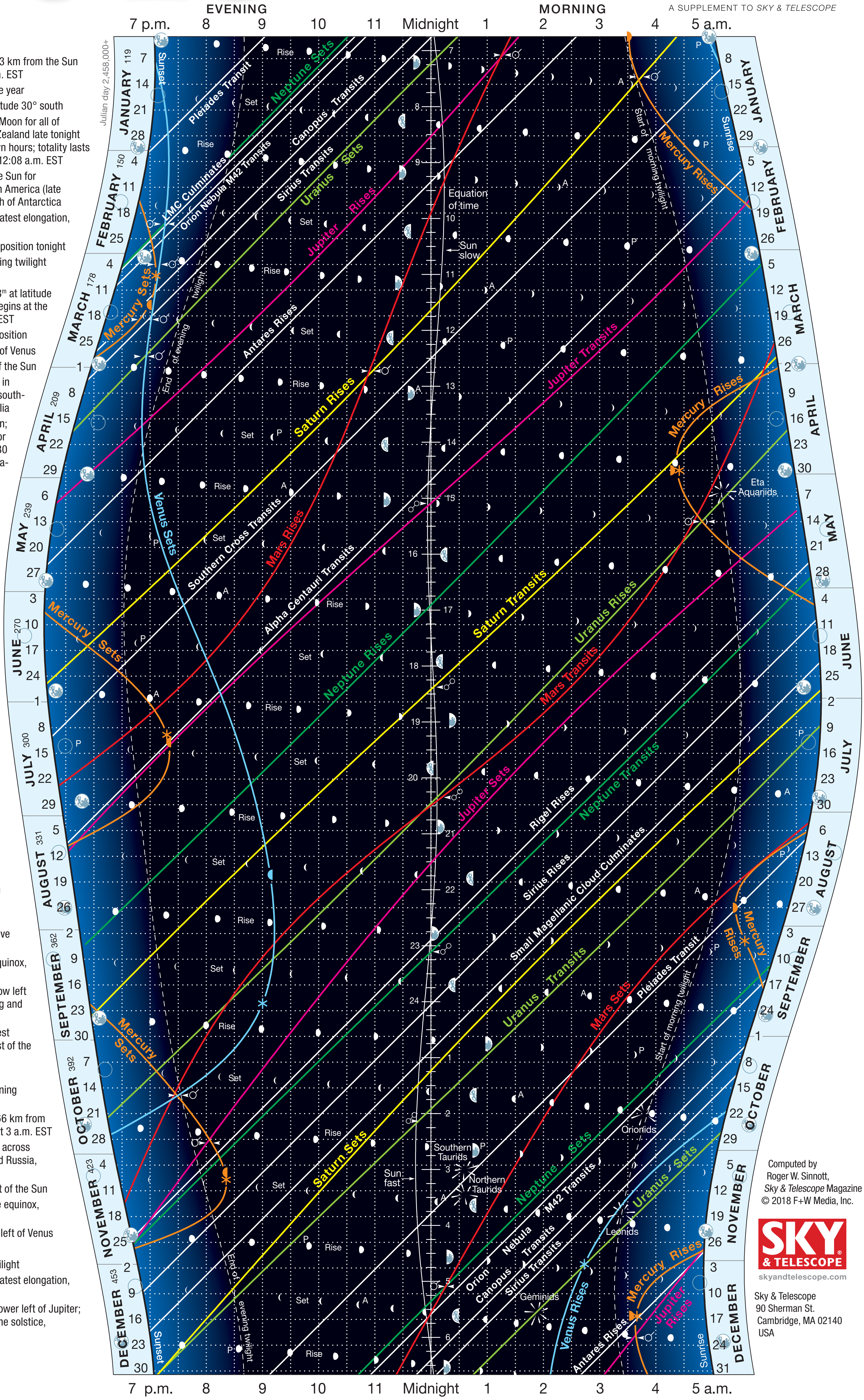
A SUPPLEMENT TO *SKY & TELESCOPE*

## EVENING SKY

- Jan 3 Earth is 147,097,233 km from the Sun (perihelion) at 4 p.m. EST
- Jan 4 Latest twilight of the year
- Jan 9 Latest sunset at latitude 30° south
- Jan 31 Total eclipse of the Moon for all of Australia and New Zealand late tonight and into the predawn hours; totality lasts from 10:51 p.m. to 12:08 a.m. EST
- Feb 15 Partial eclipse of the Sun for southernmost South America (late afternoon) and much of Antarctica
- Mar 15 Mercury attains greatest elongation, 18° east of the Sun
- May 8 Jupiter comes to opposition tonight
- Jun 8 Earliest end of evening twilight
- Jun 10 Earliest sunset
- Jun 21 Shortest day, $10^h\ 13^m$ at latitude 30° south; winter begins at the solstice, 8:07 p.m. EST
- Jun 27 Saturn reaches opposition
- Jul 10 Regulus is 1.0° left of Venus
- Jul 12 Mercury 26° east of the Sun
- Jul 13 Partial solar eclipse in early afternoon for south-easternmost Australia
- Jul 27 Mars is at opposition; total lunar eclipse for Africa between 19:30 and 21:14 UT, Australia seeing it before dawn (July 28th)
- Jul 31 Mars nearest Earth with the disk 24.3″ across
- Aug 17 Venus is 46° east of the Sun
- Sep 7 Neptune reaches opposition
- Oct 23 Uranus is at opposition
- Oct 26 Venus passes through inferior conjunction, 6° south of the Sun
- Oct 29 Mercury is 3.1° to upper left of Jupiter
- Nov 6 Mercury stands 23° east of the Sun
- Dec 7 Neptune is 0.1° to upper right of Mars
- Dec 22 Longest day, $14^h\ 05^m$ at latitude 30° south

## MORNING SKY

- Jan 2 Mercury reaches greatest elongation, 23° west of the Sun
- Jan 7 Mars is 0.2° above Jupiter
- Jan 13 Mercury is 0.8° above Saturn
- Mar 21 Fall begins at the equinox, 2:15 a.m. EST
- Apr 2 Saturn lies 1.3° below left of Mars this morning and tomorrow
- Apr 30 Mercury is at greatest elongation, 27° west of the Sun
- Jul 2 Latest sunrise
- Jul 4 Latest onset of morning twilight
- Jul 7 Earth is 152,095,566 km from the Sun (aphelion) at 3 a.m. EST
- Aug 11 Partial solar eclipse across northern Europe and Russia, and northeast Asia
- Aug 27 Mercury is 18° west of the Sun
- Sep 23 Spring begins at the equinox, 11:54 a.m. EST
- Nov 15 Spica is 1.2° above left of Venus
- Dec 4 Earliest sunrise
- Dec 9 Earliest morning twilight
- Dec 16 Mercury attains greatest elongation, 21° west of the Sun
- Dec 22 Mercury is 0.8° to lower left of Jupiter; summer begins at the solstice, 8:23 a.m. EST




Conjunction (appulse) · Greatest elongation · Greatest illuminated extent · Opposition · New Moon · First Quarter · Full Moon · Last Quarter · A Apogee · P Perigee · Waxing (moonset) · Waning (moonrise)

Computed by Roger W. Sinnott, *Sky & Telescope* Magazine



SKY & TELESCOPE

skyandtelescope.com

Sky & Telescope
90 Sherman St.
Cambridge, MA 02140
USA

# 2018 30°S Skygazer's Almanac

FOR LATITUDES NEAR 30° SOUTH

## What's in the sky tonight?

When does the Sun set, and when does twilight end? Which planets are visible? What time is moonrise?

Welcome to the *Skygazer's Almanac 2018,* a handy chart that answers these and many other questions for every night of the year. This version is plotted for skywatchers near latitude 30° south — in Australia, southern Africa, and the southern cone of South America.

For any date, the chart tells the times when astronomical events occur during the night. Dates on the chart run vertically from top to bottom. The time of night runs horizontally, from sunset at left to sunrise at right. Find the date you want on the left side of the chart, and read across toward the right to find the times of events. Times are labeled along the chart's top and bottom.

In exploring the chart, you'll find that its night-to-night patterns offer many insights into the rhythms of the heavens.

### The Events of a Single Night

To learn how to use the chart, consider some of the events of one night. We'll pick January 7, 2018.

First find "January" and "7" at the left edge. This is one of the dates for which a string of fine dots crosses the chart horizontally. Each horizontal dotted line represents the night from a Sunday evening to Monday morning. The individual dots are five minutes apart.

Every half hour (six dots), there is a vertical dotted line to aid in reading the hours of night at the chart's top or bottom. On the vertical lines, one dot is equal to one day.

A sweep of the eye shows that the line for the night of January 7–8 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 7–8 begins at the heavy black curve at left, which represents the time of sunset. Reading up to the top of the chart, we find that sunset on January 7th occurs at 7:05 p.m. *Local Mean Time*. (All times read from the chart are Local Mean Time, which can differ from your civil clock time by many minutes. More on this later.)

Moving to the right we see that at 8:40 p.m. the Pleiades transit the meridian, meaning the famous star cluster is highest in the sky. The sky is also fully dark then, because evening twilight ends with the Sun 18° below the horizon.

At 10:15 the Large Magellanic Cloud culminates (another way of saying it transits). Then the Orion Nebula (Messier 42) transits at 10:28, followed by the two brightest nighttime stars, Canopus and Sirius, at 11:16 and 11:37, respectively. Transit times of such celestial landmarks help us follow the march of constellations during the night.

On the dotted line near 11:09 p.m. we see a small Moon symbol, and the legend at the chart's bottom tells us it is at waning gibbous phase, rising. So we'll have bright moonlight from now on tonight.

Running vertically down the midnight line is a scale of hours. This shows the sidereal time (the right ascension of objects on the meridian) at midnight. On January 7–8 this is $7^h\ 09^m$. To find the sidereal time at any other time and date on the chart, locate the point for the time and date you want, then draw a line through it parallel to the white event lines of stars. See where your line intersects the sidereal-time scale at midnight. (A star's event line enters the top of the chart at the same time of night it leaves the bottom. Sometimes one of these segments is left out to avoid crowding.)

Near the midnight line is a white curve labeled *Equation of time* weaving narrowly right and left down the chart. If you regard the midnight line as the previous noon for a moment, this curve shows when the Sun crosses the meridian and is due north. On January 7th the Sun runs slow, transiting at 12:06 p.m. This variation is caused by the tilt of Earth's axis and the ellipticity of its orbit.

Then at 1:14 a.m. the bright planets Jupiter and Mars rise together, which indicates they must be fairly close in the sky. They'll be better placed for telescopic viewing toward dawn.

At 2:12 Antares, a star we usually associate with later seasons, climbs above the horizon.

The first hint of dawn — the start of morning twilight — comes at 3:32 a.m. Elusive Mercury rises quite soon thereafter, at 3:34, which is early enough before sunup that we should be able to spot it when it climbs higher. Then Saturn rises at 4:02. The Sun finally peeks above the eastern horizon at 5:07 a.m. on the morning of January 8th.

### Other Charted Information

Many of the year's most important astronomical events are listed in the chart's left-hand margin. Some are marked on the chart itself.

**Local Mean Time Corrections**

| | | | |
|---|---|---|---|
| Adelaide | +16 | Melbourne | +20 |
| Brisbane | –13 | Perth | +18 |
| Canberra | +4 | Sydney | –4 |
| Cape Town | +46 | Johannesburg | +8 |
| Durban | –3 | Port Elizabeth | +18 |
| Harare | –4 | Pretoria | +8 |
| Asunción | –10 | Rio de Janeiro | –7 |
| Buenos Aires | +54 | Santiago | +43 |
| Montevideo | +45 | São Paulo | +6 |

*Conjunctions* (close pairings) of two planets are indicated by a ☌ symbol on the planets' event lines. Here, conjunctions are indicated when the planets appear closest in the sky (at appulse), not just when they have the same ecliptic longitude or right ascension.

*Opposition* of a planet, the date when it is opposite the Sun in the sky and thus visible all night, occurs when its transit line crosses the Equation-of-time line (*not* the line for midnight). Opposition is marked there by a ☍ symbol. For instance, Saturn reaches opposition on the night of June 27–28 this year.

*Moonrise* and *moonset* can be told apart by whether the round limb — the outside edge — of the Moon symbol faces left (waxing Moon sets) or right (waning Moon rises). Or follow the nearly horizontal row of daily Moon symbols across the chart to find the word *Rise* or *Set*. Quarter Moons are indicated by a larger symbol. Full Moon is always a large bright disk whether rising or setting; the circle for new Moon is open. *P* and *A* mark dates when the Moon is at perigee and apogee (nearest and farthest from Earth, respectively).

*Mercury* and *Venus* never stray far outside the twilight bands. Their dates of greatest elongation from the Sun are shown by ◗ symbols on their rising or setting curves, and asterisks mark when their telescopic disks have the greatest illuminated extent in square arcseconds. For Venus this is also when it reaches greatest brilliancy, as on September 21st this year (evening sky), and again on December 2nd (morning).

*Meteor showers* are marked by a starburst symbol on the date of peak activity and at the time when the shower's radiant (point of origin) is highest in the night sky. This often occurs just as morning twilight begins.

*Julian dates* can be found from the numbers just after the month names on the chart's left. The Julian day, a seven-digit number, is a running count of days beginning with January 1, 4713 BC. Its first four digits this year are 2458, as indicated just off the chart's upper left margin. To find the last three digits for days in January, add 119 to the date. For instance, on January 7th we have 119 + 7 = 126, so the Julian day is 2,458,126.

## Rising or Setting Corrections

| | Declination (North or South) | | | | | |
|---|---|---|---|---|---|---|
| **South Latitude** | **0°** | **5°** | **10°** | **15°** | **20°** | **25°** |
| **10°** | 0 | 8 | 16 | 24 | 33 | 43 |
| **15°** | 0 | 6 | 12 | 19 | 26 | 33 |
| **20°** | 0 | 4 | 8 | 13 | 18 | 23 |
| **25°** | 0 | 2 | 4 | 7 | 9 | 12 |
| **30°** | 0 | 0 | 0 | 0 | 0 | 0 |
| **35°** | 0 | 2 | 5 | 7 | 10 | 13 |
| **40°** | 0 | 5 | 10 | 16 | 22 | 29 |
| **45°** | 1 | 8 | 17 | 26 | 37 | 49 |
| **50°** | 1 | 12 | 25 | 39 | 54 | 72 |

Note that the Julian day doesn't change to this value until 12:00 Universal Time (UT). In Australia, 12:00 UT falls during the evening of the same day (at 10 p.m. Eastern Standard Time, EST). Before that time, subtract 1 from the Julian day number just obtained.

## Time Corrections

All events on this southern version of the *Skygazer's Almanac* are plotted for an observer at 135° east longitude and 30° south latitude. However, you need not live near McDouall Peak, South Australia, to use the chart. Simple corrections will allow you to get times accurate to a couple of minutes anywhere in the world's south temperate latitudes.

To convert the charted time of an event into your civil (clock) time, the following corrections must be made. They are given in order of decreasing importance.

**• Daylight-saving time ("summer time").** When this is in effect, add one hour to any time read from the chart.

**• Your longitude.** The chart gives the *Local Mean Time* (LMT) of events, which differs from ordinary clock time by many minutes at most locations. Our civil time zones are standardized on particular longitudes. Examples in Australia are 150° E for the eastern states (which use Eastern Standard Time, EST), and 142.5° E for the two central states (an odd value that puts the minute hands of their clocks 30 minutes out of joint with most of the rest of the world).

If your longitude is very close to your standard time-zone meridian, luck is with you and your LMT correction is zero. Otherwise, to get standard time *add 4 minutes* to times obtained from the chart for each degree of longitude that you are *west* of your time-zone meridian. Or *subtract 4 minutes* for each degree you are *east* of it. You can look up your longitude on a map.

For instance, Melbourne, Australia (longitude 145°), is 5° west of its time-zone meridian (150°). So at Melbourne, add 20 minutes to any time obtained from the chart. The result is standard time.

Find your Local Mean Time correction and memorize it; you will use it always. The table below left has the corrections, in minutes, for some major cities.

**• Rising and setting.** Times of rising and setting need correction if your latitude differs from 30° south. This effect depends strongly on a star or planet's declination. The declinations of the Sun and planets are listed in *Sky & Telescope*.

If your site is *south* of latitude 30° S, an object with a south declination stays above the horizon *longer* than the chart shows (it rises earlier and sets later), while one with a north declination spends less time above the horizon. If you are *north* of 30° S, the effect is just the reverse. With these rules in mind, you can gauge the number of minutes for correcting a rise or set time using the table above.

Finally, the Moon's rapid orbital motion alters lunar rising and setting times slightly if your longitude differs from 135° E. The Moon rises and sets about two minutes earlier than the chart shows for each time zone east of central Australia, and two minutes later for each time zone west of there. Observers in southern Africa can simply shift the Moon symbol a third of the way to that for the following date. Those in South America can shift it about halfway there.



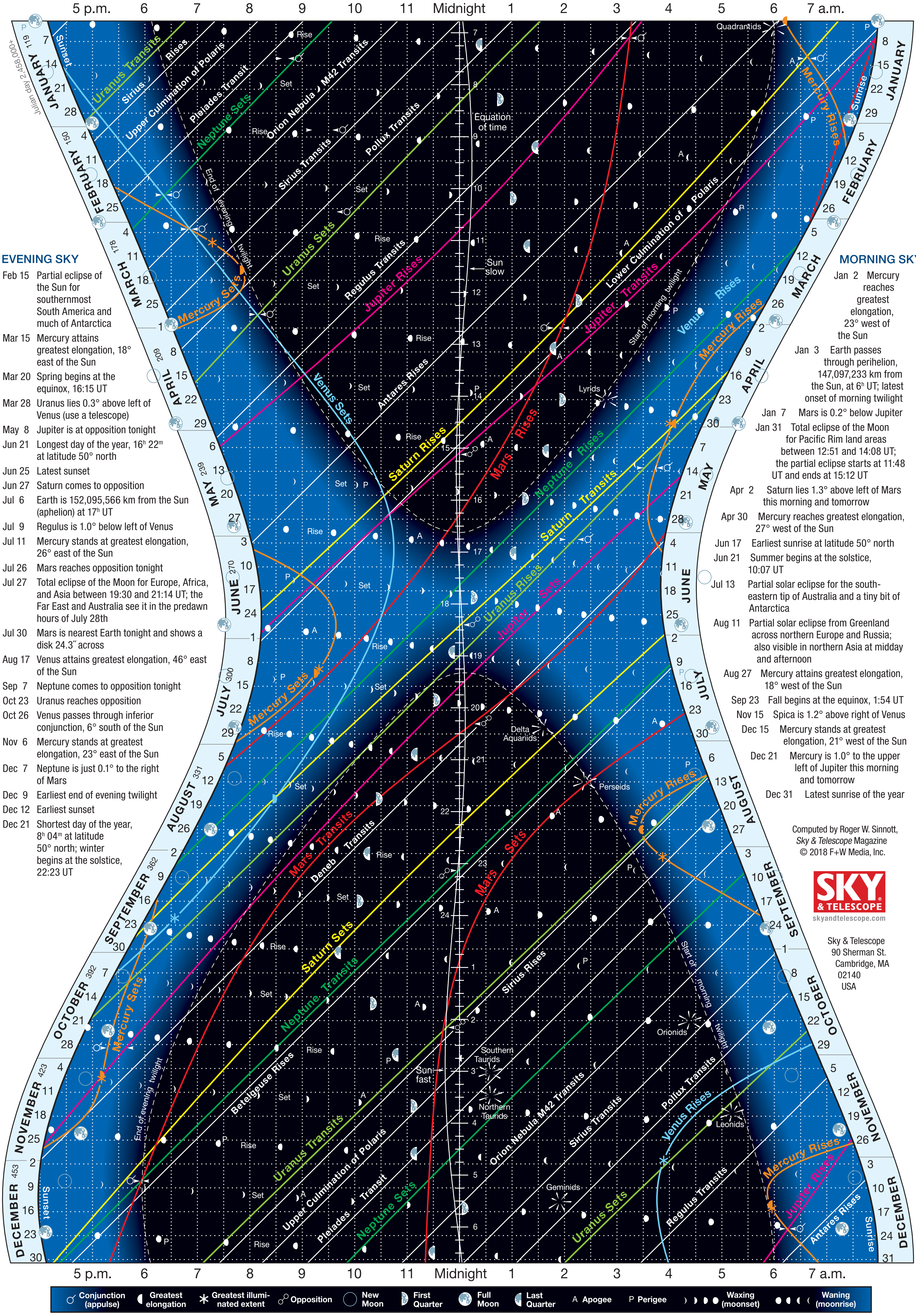
For reprints (item SGA18S, $5.95 each postpaid) or to order a similar chart for north latitude 40° or 50°, contact *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140, USA; phone +1 617-864-7360, fax +1 617-864-6117. Send an e-mail to skyprodservice@skyandtelescope.com, or you can visit our online store at shopatsky.com.

skyandtelescope.com

# 2018 50°N Skygazer's Almanac

FOR LATITUDES NEAR 50° NORTH

A SUPPLEMENT TO *SKY & TELESCOPE*




## EVENING SKY

- **Feb 15** Partial eclipse of the Sun for southernmost South America and much of Antarctica
- **Mar 15** Mercury attains greatest elongation, 18° east of the Sun
- **Mar 20** Spring begins at the equinox, 16:15 UT
- **Mar 28** Uranus lies 0.3° above left of Venus (use a telescope)
- **May 8** Jupiter is at opposition tonight
- **Jun 21** Longest day of the year, $16^h 22^m$ at latitude 50° north
- **Jun 25** Latest sunset
- **Jun 27** Saturn comes to opposition
- **Jul 6** Earth is 152,095,566 km from the Sun (aphelion) at $17^h$ UT
- **Jul 9** Regulus is 1.0° below left of Venus
- **Jul 11** Mercury stands at greatest elongation, 26° east of the Sun
- **Jul 26** Mars reaches opposition tonight
- **Jul 27** Total eclipse of the Moon for Europe, Africa, and Asia between 19:30 and 21:14 UT; the Far East and Australia see it in the predawn hours of July 28th
- **Jul 30** Mars is nearest Earth tonight and shows a disk 24.3″ across
- **Aug 17** Venus attains greatest elongation, 46° east of the Sun
- **Sep 7** Neptune comes to opposition tonight
- **Oct 23** Uranus reaches opposition
- **Oct 26** Venus passes through inferior conjunction, 6° south of the Sun
- **Nov 6** Mercury stands at greatest elongation, 23° east of the Sun
- **Dec 7** Neptune is just 0.1° to the right of Mars
- **Dec 9** Earliest end of evening twilight
- **Dec 12** Earliest sunset
- **Dec 21** Shortest day of the year, $8^h 04^m$ at latitude 50° north; winter begins at the solstice, 22:23 UT

## MORNING SKY

- **Jan 2** Mercury reaches greatest elongation, 23° west of the Sun
- **Jan 3** Earth passes through perihelion, 147,097,233 km from the Sun, at $6^h$ UT; latest onset of morning twilight
- **Jan 7** Mars is 0.2° below Jupiter
- **Jan 31** Total eclipse of the Moon for Pacific Rim land areas between 12:51 and 14:08 UT; the partial eclipse starts at 11:48 UT and ends at 15:12 UT
- **Apr 2** Saturn lies 1.3° above left of Mars this morning and tomorrow
- **Apr 30** Mercury reaches greatest elongation, 27° west of the Sun
- **Jun 17** Earliest sunrise at latitude 50° north
- **Jun 21** Summer begins at the solstice, 10:07 UT
- **Jul 13** Partial solar eclipse for the south-eastern tip of Australia and a tiny bit of Antarctica
- **Aug 11** Partial solar eclipse from Greenland across northern Europe and Russia; also visible in northern Asia at midday and afternoon
- **Aug 27** Mercury attains greatest elongation, 18° west of the Sun
- **Sep 23** Fall begins at the equinox, 1:54 UT
- **Nov 15** Spica is 1.2° above right of Venus
- **Dec 15** Mercury stands at greatest elongation, 21° west of the Sun
- **Dec 21** Mercury is 1.0° to the upper left of Jupiter this morning and tomorrow
- **Dec 31** Latest sunrise of the year


Computed by Roger W. Sinnott, *Sky & Telescope* Magazine




SKY & TELESCOPE
skyandtelescope.com


Sky & Telescope
90 Sherman St.
Cambridge, MA
02140
USA

# 2018 50°N Skygazer's Almanac

FOR LATITUDES NEAR 50° NORTH

## *What's in the sky tonight?*

When does the Sun set, and when does twilight end? Which planets are visible? What time does the Moon rise?

Welcome to the *Skygazer's Almanac 2018,* a handy chart that answers these and many other questions for every night of the year. This version is plotted for skywatchers near latitude 50° north — in the United Kingdom, northern Europe, Canada, and Russia.

For any date, the chart tells the times when astronomical events occur during the night. Dates on the chart run vertically from top to bottom. The time of night runs horizontally, from sunset at left to sunrise at right. Find the date you want on the left side of the chart, and read across toward the right to find the times of events. Times are labeled along the chart's top and bottom.

In exploring the chart you'll find that its night-to-night patterns offer many insights into the rhythms of the heavens.

### The Events of a Single Night

To learn how to use the chart, consider some of the events of one night. We'll pick January 7, 2018.

First find "January" and "7" at the left edge. This is one of the dates for which a string of fine dots crosses the chart horizontally. Each horizontal dotted line represents the night from a Sunday evening to Monday morning. The individual dots are five minutes apart.

Every half hour (six dots), there is a vertical dotted line to aid in reading the hours of night at the chart's top or bottom. On the vertical lines, one dot is equal to one day.

A sweep of the eye shows that the line for the night of January 7–8 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 7–8 begins at the heavy black curve at left, which represents the time of sunset. Reading up to the top of the chart, we find that sunset on January 7th occurs at 4:16 p.m. *Local Mean Time*. (All times on the chart are Local Mean Time, which can differ from your civil clock time by many minutes. More on this later.)

Moving to the right, we see that evening twilight ends at 6:13, marking the time when the Sun is 18° below the horizon and the sky is fully dark.

At 6:57 p.m. the bright star Sirius rises. Then at 7:46 Polaris, the North Star, reaches upper culmination. This is when Polaris stands directly above the north celestial pole (by 40′, or 39′ later this year), a good opportunity to check the alignment of an equatorial telescope.

The Pleiades star cluster in Taurus transits the meridian at 8:39, followed by the Orion Nebula, Messier 42, at 10:27. Transits of celestial landmarks tell when they are highest in the sky and remind us where the constellations are all night.

Near 11:13 on the dotted line is a small Moon symbol, and the legend at the chart's bottom tells us it is at waning gibbous phase, rising. So we'll have bright moonlight for the rest of the night.

Running vertically down the midnight line is a scale of hours. This shows the sidereal time (the right ascension of objects on the meridian) at midnight. On January 7–8 this is $7^h\ 10^m$. To find the sidereal time at any other time and date on the chart, locate the point for the time and date you want, then draw a line through it parallel to the white event lines of stars. See where your line intersects the sidereal-time scale at midnight. (A star's event line enters the top of the chart at the same time of night it leaves the bottom. Sometimes one of these segments is left out to avoid crowding.)

Near the midnight line is a white curve labeled *Equation of time* weaving narrowly right and left down the chart. If you regard the midnight line as the previous noon for a moment, this curve shows when the Sun crosses the meridian and is due south. On January 7th the Sun runs slow, transiting at 12:06 p.m. This variation is caused by the tilt of Earth's axis and the ellipticity of its orbit.

The giant planet Jupiter rises at 3:10 a.m., and Mars at 3:14. This coincidence means they are close in the sky and will be higher up for viewing toward dawn.

Then at 5:40 Antares, a star we usually associate with a later season, rises.

The first hint of dawn — the start of morning twilight — comes at 5:59 a.m. Elusive Mercury rises at 6:26, and then Saturn at 6:53. The Sun finally peeks above the eastern horizon at 7:57 a.m. on the morning of January 8th.

### Other Charted Information

Many of the year's chief astronomical events are listed in the chart's evening and morning margins. Some are marked on the chart itself.

#### Local Mean Time Corrections

| | | | |
|---|---|---|---|
| Amsterdam | +40 | Manchester | +8 |
| Belfast | +24 | Montreal | –6 |
| Berlin | +6 | Moscow | +26 |
| Bordeaux | +62 | Munich | +14 |
| Bremen | +24 | Oslo | +17 |
| Brussels | +44 | Ottawa | +3 |
| Bucharest | +16 | Paris | +51 |
| Budapest | –16 | Prague | +2 |
| Calgary | +36 | Quebec | –15 |
| Copenhagen | +10 | Regina | +58 |
| Dublin | +25 | Reykjavik | +88 |
| Geneva | +35 | St. John's | +1 |
| Glasgow | +16 | Stockholm | –12 |
| Halifax | +14 | Toronto | +18 |
| Hamburg | +20 | Vancouver | +12 |
| Helsinki | +20 | Vienna | –5 |
| Kiev | –2 | Warsaw | –24 |
| London | 0 | Winnipeg | +29 |
| Lyons | +41 | Zurich | +24 |

*Conjunctions* (close pairings) of two planets are marked on the chart by a ☌ symbol on the planets' event lines. Here, conjunctions are considered to occur when the planets actually appear closest together in the sky (at appulse), not merely when they share the same ecliptic longitude or right ascension.

*Opposition* of a planet, the date when it is opposite the Sun in the sky and thus visible all night, occurs when its transit line crosses the Equation-of-time line (*not* the line for midnight). Opposition is indicated there by a ☍ symbol. For instance, Saturn reaches opposition on the night of June 27–28 this year.

*Moonrise* and *moonset* can be told apart by whether the round limb — the outside edge — of the Moon symbol faces right (waxing Moon sets) or left (waning Moon rises). Or follow the nearly horizontal row of daily Moon symbols across the chart to find the word *Rise* or *Set*. Quarter Moons are indicated by a larger symbol. Full Moon is always a large bright disk whether rising or setting; the circle for new Moon is open. *P* and *A* mark dates when the Moon is at perigee and apogee (nearest and farthest from Earth, respectively).

*Mercury* and *Venus* never stray far outside the twilight bands. Their dates of greatest elongation from the Sun are shown by ◗ symbols on their rising or setting curves. Asterisks mark the dates when their disks in telescopes show the greatest illuminated extent in square arcseconds. In the case of Venus, this is also very nearly the date when the planet reaches greatest brilliancy, as on the evening of September 21st (but very low) and again on the morning of December 2nd this year.

*Meteor showers* are marked by a starburst symbol at the date of peak activity and the time when the shower's radiant is highest in the night sky. This is often just as twilight begins before dawn.

*Julian dates* can be found from the numbers just after the month names on the chart's left. The Julian day, a seven-digit number, is a running count of days beginning with January 1, 4713 BC. Its first four digits this year are 2458, as indicated just off the chart's upper left margin. To find the last three digits for evenings in January, add 119 to the date.

**Rising or Setting Corrections**

| North Latitude | Declination (North or South) 0° | 5° | 10° | 15° | 20° | 25° |
|---|---|---|---|---|---|---|
| 60° | 1 | 11 | 23 | 36 | 53 | 80 |
| 55° | 0 | 5 | 10 | 16 | 23 | 32 |
| 50° | 0 | 0 | 0 | 0 | 0 | 0 |
| 45° | 0 | 4 | 8 | 13 | 18 | 24 |
| 40° | 1 | 8 | 15 | 23 | 32 | 43 |
| 35° | 1 | 10 | 20 | 31 | 44 | 68 |
| 30° | 1 | 12 | 25 | 39 | 54 | 72 |
| 25° | 1 | 15 | 30 | 46 | 64 | 84 |

For instance, on the evening of January 7th we have 119 + 7 = 126, so the Julian day is 2,458,126. For European observers this number applies all night, because the next Julian day always begins at 12:00 Universal Time (noon Greenwich Mean Time).

## Time Corrections

All events on this *Skygazer's Almanac* are plotted for an observer at 0° longitude and 50° north latitude, a reasonable compromise for the countries of northern and central Europe. However, you need not be on a boat in the English Channel to use the chart. Simple corrections will allow you to get times accurate to a couple of minutes anywhere in the world's north temperate latitudes.

To convert the charted time of an event into your civil (clock) time, the following corrections must be made. They are given in order of decreasing importance:

• **DAYLIGHT-SAVING TIME (OR "SUMMER TIME").** When this is in effect, add one hour to any time that you obtain from the chart.

• **YOUR LONGITUDE.** The chart gives the *Local Mean Time* (LMT) of events, which differs from ordinary clock time by a number of minutes at most locations. Our civil time zones are standardized on particular longitudes. Examples in Europe are Greenwich Mean Time (or Universal Time), 0°; Central European Time, 15° E; and East European Time, 30°. If your longitude is very close to one of these (as is true for London), luck is with you and this correction is zero. Otherwise, to get standard time *add 4 minutes* to times obtained from the chart for each degree of longitude that you are *west* of your time-zone meridian. Or *subtract 4 minutes* for each degree you are *east* of it. You can look up your longitude on a map or website.

For instance, Copenhagen (longitude 12.5° east) is 2.5° west of the Central European Time meridian. So at Copenhagen, add 10 minutes to any time obtained from the chart. The result is Central European Standard Time.

Find your local-time correction and memorize it; you will use it always. In the table below left are the corrections from local to standard time, in minutes, for some major cities.

• **RISING AND SETTING.** Times of rising and setting need correction if your latitude differs from 50° north. This effect depends strongly on a star or planet's declination. (The changing declinations of the Sun and planets can be found in each issue of *Sky & Telescope*).

If your site is north of latitude 50°, then an object with a north declination stays above the horizon longer than the chart shows (it rises earlier and sets later), while one with a south declination spends less time above the horizon. At a site south of 50°, the effect is just the reverse. Keeping these rules in mind, you can gauge the approximate number of minutes by which to correct a rising or setting time from the table at above.

Finally, the Moon's rapid orbital motion alters lunar rising and setting times slightly if your longitude differs from 0°. The Moon rises and sets about two minutes earlier than the chart shows for each time zone east of Greenwich Mean Time, and two minutes later for each time zone west of Greenwich Mean Time.

*Skygazer's Almanac 2018* is a supplement to *Sky & Telescope*. 

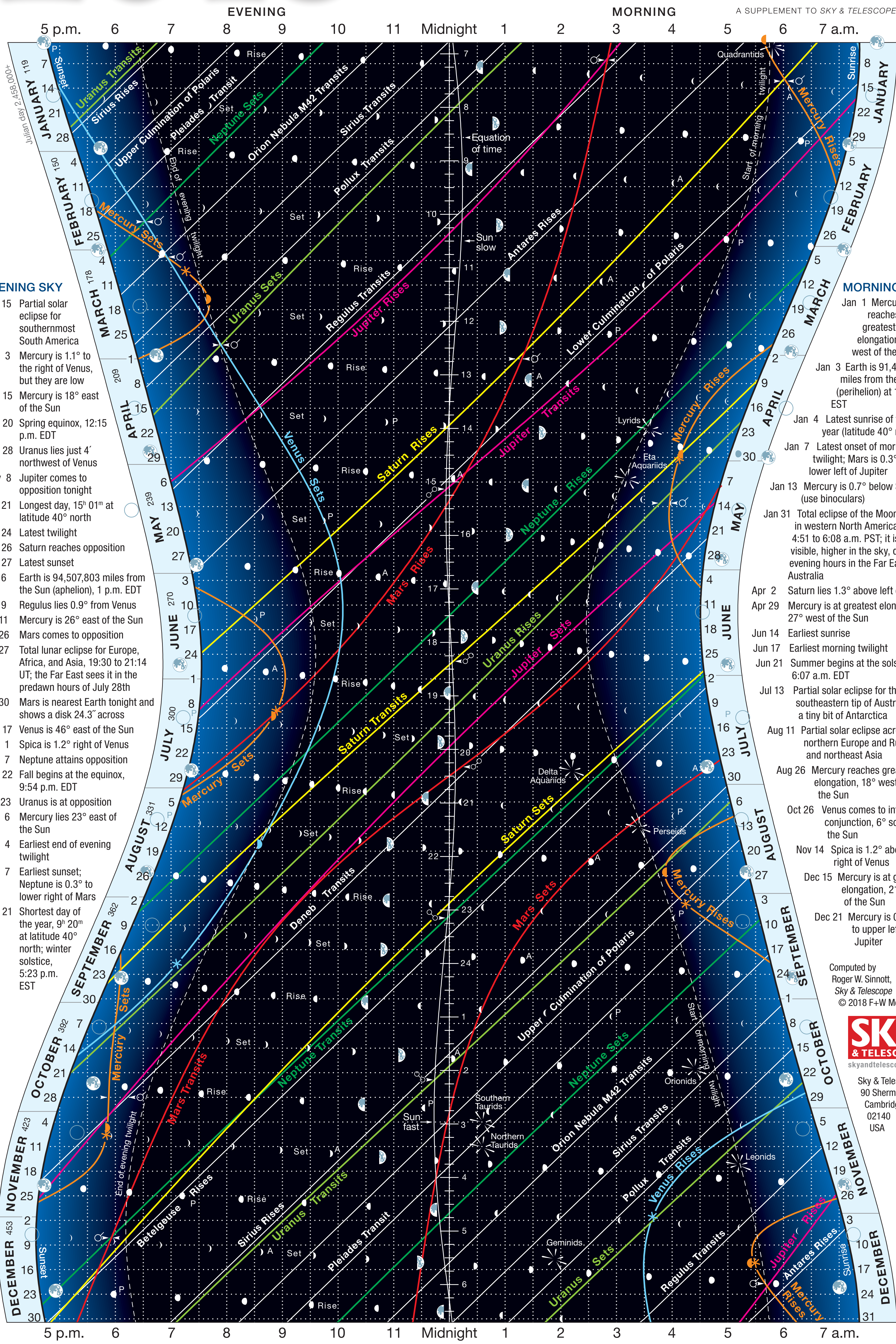
For reprints (item SGA18E, $5.95 each postpaid) or to order a similar chart for latitude 40° north or 30° south, contact *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140, USA; phone +1 617-864-7360, fax +1 617-864-6117. E-mail skyprodservice@skyandtelescope.com, or visit our online store at shopatsky.com.

skyandtelescope.com

# 2018 40°N Skygazer's Almanac

FOR LATITUDES NEAR 40° NORTH

A SUPPLEMENT TO *SKY & TELESCOPE*




## EVENING SKY

- Feb 15 Partial solar eclipse for southernmost South America
- Mar 3 Mercury is 1.1° to the right of Venus, but they are low
- Mar 15 Mercury is 18° east of the Sun
- Mar 20 Spring equinox, 12:15 p.m. EDT
- Mar 28 Uranus lies just 4′ northwest of Venus
- May 8 Jupiter comes to opposition tonight
- Jun 21 Longest day, $15^h\ 01^m$ at latitude 40° north
- Jun 24 Latest twilight
- Jun 26 Saturn reaches opposition
- Jun 27 Latest sunset
- Jul 6 Earth is 94,507,803 miles from the Sun (aphelion), 1 p.m. EDT
- Jul 9 Regulus lies 0.9° from Venus
- Jul 11 Mercury is 26° east of the Sun
- Jul 26 Mars comes to opposition
- Jul 27 Total lunar eclipse for Europe, Africa, and Asia, 19:30 to 21:14 UT; the Far East sees it in the predawn hours of July 28th
- Jul 30 Mars is nearest Earth tonight and shows a disk 24.3″ across
- Aug 17 Venus is 46° east of the Sun
- Sep 1 Spica is 1.2° right of Venus
- Sep 7 Neptune attains opposition
- Sep 22 Fall begins at the equinox, 9:54 p.m. EDT
- Oct 23 Uranus is at opposition
- Nov 6 Mercury lies 23° east of the Sun
- Dec 4 Earliest end of evening twilight
- Dec 7 Earliest sunset; Neptune is 0.3° to lower right of Mars
- Dec 21 Shortest day of the year, $9^h\ 20^m$ at latitude 40° north; winter solstice, 5:23 p.m. EST

## MORNING SKY

- Jan 1 Mercury reaches greatest elongation, 23° west of the Sun
- Jan 3 Earth is 91,401,983 miles from the Sun (perihelion) at 1 a.m. EST
- Jan 4 Latest sunrise of the year (latitude 40° north)
- Jan 7 Latest onset of morning twilight; Mars is 0.3° to lower left of Jupiter
- Jan 13 Mercury is 0.7° below Saturn (use binoculars)
- Jan 31 Total eclipse of the Moon visible in western North America from 4:51 to 6:08 a.m. PST; it is also visible, higher in the sky, during evening hours in the Far East and Australia
- Apr 2 Saturn lies 1.3° above left of Mars
- Apr 29 Mercury is at greatest elongation, 27° west of the Sun
- Jun 14 Earliest sunrise
- Jun 17 Earliest morning twilight
- Jun 21 Summer begins at the solstice, 6:07 a.m. EDT
- Jul 13 Partial solar eclipse for the southeastern tip of Australia and a tiny bit of Antarctica
- Aug 11 Partial solar eclipse across northern Europe and Russia, and northeast Asia
- Aug 26 Mercury reaches greatest elongation, 18° west of the Sun
- Oct 26 Venus comes to inferior conjunction, 6° south of the Sun
- Nov 14 Spica is 1.2° above right of Venus
- Dec 15 Mercury is at greatest elongation, 21° west of the Sun
- Dec 21 Mercury is 0.9° to upper left of Jupiter


Computed by Roger W. Sinnott, *Sky & Telescope*





SKY & TELESCOPE
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USA


Conjunction (appulse) · Greatest elongation · Greatest illuminated extent · Opposition · New Moon · First Quarter · Full Moon · Last Quarter · A Apogee · P Perigee · Waxing (moonset) · Waning (moonrise)

# 2018 40° N Skygazer's Almanac

FOR LATITUDES NEAR 40° NORTH

## *What's in the sky tonight?*

When does the Sun set, and when does twilight end? Which planets are visible? What time does the Moon rise?

Welcome to the *Skygazer's Almanac 2018,* a handy chart that answers these and many other questions for every night of the year. It is plotted for skywatchers near latitude 40° north — in the United States, the Mediterranean countries, Japan, and much of China.

For any date, the chart tells the times when astronomical events occur during the night. Dates on the chart run vertically from top to bottom. The time of night runs horizontally, from sunset at left to sunrise at right. Find the date you want on the left side of the chart, and read across toward the right to find the times of events. Times are labeled along the chart's top and bottom.

In exploring the chart you'll find that its night-to-night patterns offer many insights into the rhythms of the heavens.

### The Events of a Single Night

To learn how to use the chart, consider some of the events of one night. We'll pick January 7, 2018.

First find "January" and "7" at the left edge. This is one of the dates for which a string of fine dots crosses the chart horizontally. Each horizontal dotted line represents the night from a Sunday evening to Monday morning. The individual dots are five minutes apart.

Every half hour (six dots), there is a vertical dotted line to aid in reading the hours of night at the chart's top or bottom. On the vertical lines, one dot is equal to one day.

A sweep of the eye shows that the line for the night of January 7–8 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 7–8 begins at the heavy black curve at left, which represents the time of sunset. Reading up to the top of the chart, we find that sunset on January 7th occurs at 4:51 p.m. *Local Mean Time*. (All times on the chart are Local Mean Time, which can differ from your clock time. More on this later.)

Moving to the right, we see that Uranus transits the meridian at 6:22 p.m., meaning the faint planet is due south and highest in the sky. Since the sky is now quite dark, this would be a good time to look for Uranus in a telescope. Evening twilight technically ends at 6:28, the time when the Sun is 18° below the horizon. The brightest nighttime star, Sirius, rises 3 minutes later.

At 7:45 Polaris, the North Star, reaches upper culmination. This means it stands directly above the north celestial pole (by 40′ now, and 39′ later this year), a good time to check the alignment of an equatorial telescope.

At 8:38 p.m. comes the transit of the famous Pleiades cluster in Taurus, followed at 10:26 by the Orion Nebula, M42. Transits of such celestial landmarks help indicate when they are best placed for viewing, and where the constellations are during the night.

Near 11:31 is a Moon symbol, and the legend at the chart's bottom tells us it is at waning gibbous phase, rising. (So the Moon is up for the rest of the night.)

Running vertically down the midnight line is a scale of hours. This shows the sidereal time (the right ascension of objects on the meridian) at midnight. On January 7–8 this is $7^h\ 11^m$. To find the sidereal time at any other time and date on the chart, locate that point and draw a line through it parallel to the white event lines of stars. See where your line intersects the sidereal-time scale at midnight. (A star's event line enters the top of the chart at the same time of night it leaves the bottom. Sometimes one of these segments is left out to avoid crowding.)

Near the midnight line is a white curve labeled *Equation of time* weaving narrowly right and left down the chart. If you regard the midnight line as noon for a moment, this curve shows when the Sun crosses the meridian and is due south. On January 7th the Sun runs slow, transiting at 12:06 p.m. This variation is caused by the tilt of Earth's axis and the ellipticity of its orbit.

Giant planet Jupiter rises at 2:46 a.m. on January 8th, and Mars only 4 minutes later. This near coincidence means they are quite close in the sky, so it's no surprise a conjunction symbol (discussed later) appears next to their rise lines just one day earlier on the chart.

Bright Regulus transits at 2:58. Then a star we usually associate with a much later season, Antares, rises at 4:54.

The first hint of dawn — start of morning twilight — comes at 5:45 a.m. And this morning elusive Mercury rises at 5:51, well before the Sun. The Sun finally peeks above the horizon at 7:22 a.m. on January 8th.

### Other Charted Information

Many of the year's chief astronomical events are listed in the chart's evening and morning margins. Some are marked on the chart itself.

*Conjunctions* (close pairings) of two planets are indicated by a ☌ symbol on the planets' event lines. Here, conjunctions are considered to occur when the planets actually appear closest in the sky (at appulse), not merely when they share the same ecliptic longitude or right ascension.

*Opposition* of a planet, the date when it is opposite the Sun in the sky and thus visible all night, occurs roughly when its transit line crosses the Equation-of-time line (*not* the line for midnight). Opposition is marked there by a ☍ symbol, as for Saturn on the night of June 26–27.

*Moonrise* and *moonset* can be told apart by whether the round limb — the outside edge — of the Moon symbol faces right (waxing Moon sets) or left (waning Moon rises). Or follow the nearly horizontal row of daily Moon symbols across the chart to find the word *Rise* or *Set*. Quarter Moons are indicated by a larger symbol. Full Moon is always a large bright disk whether rising or setting; the circle for new Moon is open. *P* and *A* mark dates when the Moon is at perigee and apogee (nearest and farthest from Earth, respectively).

*Mercury* and *Venus* never stray far from the twilight bands. Their dates of greatest elongation from the Sun are shown by ◗ on their rising or setting curves. Asterisks mark their dates of greatest illuminated extent in square arcseconds. For Venus this is also when it has greatest brilliancy, as on September 20th (evening sky) and December 2nd (morning).

*Meteor showers* are marked by a starburst symbol on the date of peak activity and at the time when the shower's radiant is highest in the night sky. This is often just as morning twilight begins.

*Julian dates* can be found from the numbers just after the month names on the chart's left. The Julian day, a seven-digit number, is a running count of days beginning with January 1, 4713 BC. Its first four digits this year are 2458, as indicated just off the chart's upper left margin. To find the last three digits for evenings in January, add 119 to the date. For instance, on the evening of January 7th we have 119 + 7 = 126, so the Julian day is 2,458,126. For North American observers this number applies all night, because the next Julian day always begins at 12:00 Universal Time (6:00 a.m. Central Standard Time).

## Time Corrections

All events on this *Skygazer's Almanac* are plotted for an observer at 90° west longitude and 40° north latitude, near the population center of North America. However, you need not live near Peoria, Illinois, to use the chart. Simple corrections will allow you to get times accurate to a couple of minutes anywhere in the world's north temperate latitudes.

To convert the charted time of an event to your civil (clock) time, the following corrections must be made. They are listed in decreasing importance:

• **DAYLIGHT-SAVING TIME.** When this is in effect, add one hour to any time obtained from the chart.

• **YOUR LONGITUDE.** The chart gives the *Local Mean Time* (LMT) of events, which differs from ordinary clock time by a number of minutes at most locations. Our civil time zones are standardized on particular longitudes. Examples in North America are Eastern Time, 75° W; Central, 90°; Mountain, 105°; and Pacific, 120°. If your longitude is very close to one of these (as is true for New Orleans and Denver), luck is with you and this correction is zero. Otherwise, to get standard time *add 4 minutes* to times obtained from the chart for each degree of longitude that you are *west* of your time-zone meridian. Or *subtract 4 minutes* for each degree you are *east* of it.

For instance, Washington, DC (longitude 77°), is 2° west of the Eastern Time meridian. So at Washington, add 8 minutes to any time obtained from the chart. The result is Eastern Standard Time.

Find your time adjustment and memorize it. The table below shows the corrections from local to standard time, in minutes, for some major cities.

• **RISING AND SETTING.** These times need correction if your latitude differs from 40° north. This effect depends strongly on a star or planet's declination (listed monthly in *Sky & Telescope*).

If your site is *north* of latitude 40°, then an object with a north declination stays above the horizon *longer* than the chart shows (it rises earlier and sets later), whereas one with a south declination spends less time above the horizon. At a site *south* of 40°, the effect is just the reverse. Keeping these rules in mind, you can gauge the approximate number of minutes by which to correct a rising or setting time from the table above.

Finally, the Moon's rapid orbital motion affects lunar rising and setting times if your longitude differs from 90° west. The Moon rises and sets about two minutes earlier than the chart shows for each time zone east of Central Time, and two minutes later for each time zone west of it. European observers can simply shift each rising or setting Moon symbol leftward a quarter of the way toward the one for the previous night.

### Rising or Setting Corrections

| North Latitude | Declination (North or South) 0° | 5° | 10° | 15° | 20° | 25° |
|---|---|---|---|---|---|---|
| 50° | 0 | 7 | 14 | 23 | 32 | 43 |
| 45° | 0 | 3 | 7 | 10 | 14 | 19 |
| 40° | 0 | 0 | 0 | 0 | 0 | 0 |
| 35° | 0 | 3 | 6 | 9 | 12 | 16 |
| 30° | 0 | 5 | 11 | 16 | 23 | 30 |
| 25° | 0 | 8 | 16 | 24 | 32 | 42 |

### Local Mean Time Corrections

| | | | |
|---|---|---|---|
| Atlanta | +38 | Los Angeles | –7 |
| Boise | +45 | Memphis | 0 |
| Boston | –16 | Miami | +21 |
| Buffalo | +15 | Minneapolis | +13 |
| Chicago | –10 | New Orleans | 0 |
| Cleveland | +27 | New York | –4 |
| Dallas | +27 | Philadelphia | +1 |
| Denver | 0 | Phoenix | +28 |
| Detroit | +32 | Pittsburgh | +20 |
| El Paso | +6 | St. Louis | +1 |
| Helena | +28 | Salt Lake City | +28 |
| Honolulu | +31 | San Francisco | +10 |
| Houston | +21 | Santa Fe | +4 |
| Indianapolis | +44 | Seattle | +10 |
| Jacksonville | +27 | Tulsa | +24 |
| Kansas City | +18 | Washington | +8 |
| Athens | +25 | Lisbon | +36 |
| Baghdad | +3 | Madrid | +75 |
| Beijing | +14 | New Delhi | +21 |
| Belgrade | –22 | Rome | +10 |
| Cairo | –8 | Seoul | +32 |
| Istanbul | +4 | Tehran | +4 |
| Jerusalem | –21 | Tokyo | –19 |

*Skygazer's Almanac 2018* is a supplement to *Sky & Telescope* magazine. 

For reprints (item SGA18R, $4.95 each postpaid) or to order a similar chart for latitude 50° north or 30° south, contact *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140, USA; phone 888-253-0230, fax 617-864-6117. Send an e-mail to skyprodservice@skyandtelescope.com, or you can visit our online store at shopatsky.com.

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