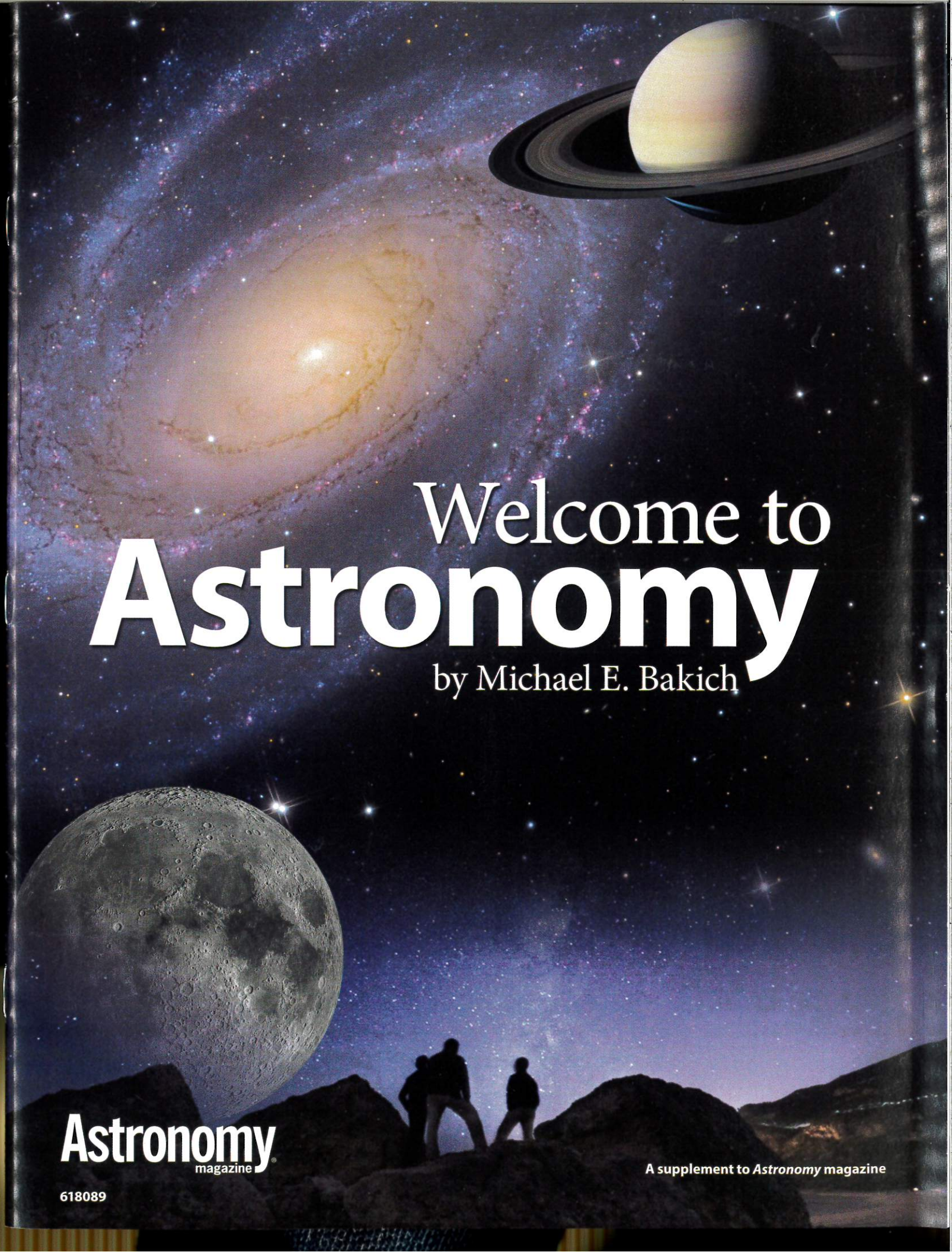

Welcome to Astronomy

by Michael E. Bakich

Astronomy magazine

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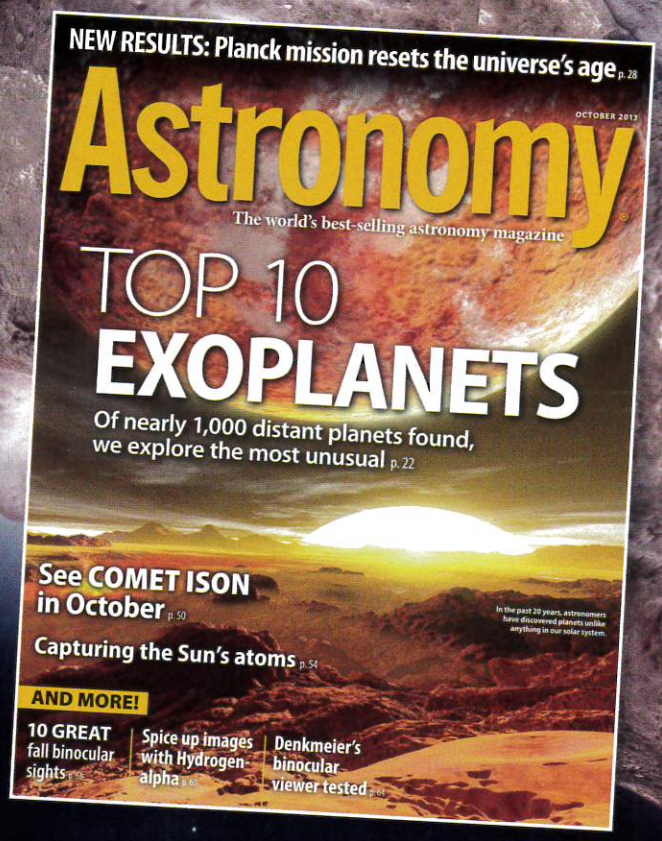

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COVER IMAGES: MATTIAS MALMER/CASSINI IMAGING TEAM (SATURN); ADAM BLOCK/MOUNT LEMMON SKYCENTER (SPIRAL GALAXY);

Naked-eye astronomy

Every clear evening when the Sun sets, the sky darkens and the stars come out. As our local piece of planet Earth turns away from the Sun and daytime fades into night, we look out toward the universe.

The simplest way to discover the stars is to begin as the earliest observers began, using just your own two eyes. If this evening is clear, why not step outside and spot a few star patterns?

Getting oriented

Under the night sky, take a look around. Can you find the Big Dipper in the north? It may be high in the sky and upside-down or near the horizon. It's a bit longer than your hand at arm's length with the fingers spread. The Dipper's stars form part of Ursa Major the Great Bear. The two outer stars in the "bowl" point toward Polaris, the North Star. Polaris is part of a constellation called Ursa Minor the Little Bear.

If you don't see bears, don't worry. Constellations are invented patterns that began as pictures in the sky to help early people remember important myths and legends.

Some constellations, such as spring's Leo the Lion, summer's Scorpius the Scorpion, and winter's Taurus the Bull, are prehistoric. They first appeared in records at the dawn of history. Others were invented more recently. Today, 88 constellations cover the sky with no gaps between them.

Imagine this photographer's surprise when a brilliant bolide (an exploding meteor) superimposed itself on her image of an aurora. The bright dot to the far left of the meteor is Jupiter. SHANNON BILESKI

Starlight, star bright

As you look at the constellations, you'll notice that stars differ in brightness. Astronomers rank stars on a scale that started with ancient Greek skywatchers. They used six "magnitudes." Current astronomers add decimals to note small steps in brightness and even negative magnitudes for bright objects. Just remember that a larger magnitude means a dimmer star.

Every star has a magnitude, but only a few hundred have names. Many star names come from their place in the constellation as described by the ancients. For example, Rigel, which is Orion the Hunter's left knee, means "left leg of the giant" in Arabic.

Each hour, stars move westward about as far as your fist held at arm's length with the thumb extended. If you look north, figures like the Big Dipper creep around Polaris like the hands of a giant clock running backward. Besides this daily motion due to Earth's rotation, the constellations also slip westward as weeks pass. This seasonal movement reflects Earth's yearly travel in its orbit around the Sun.

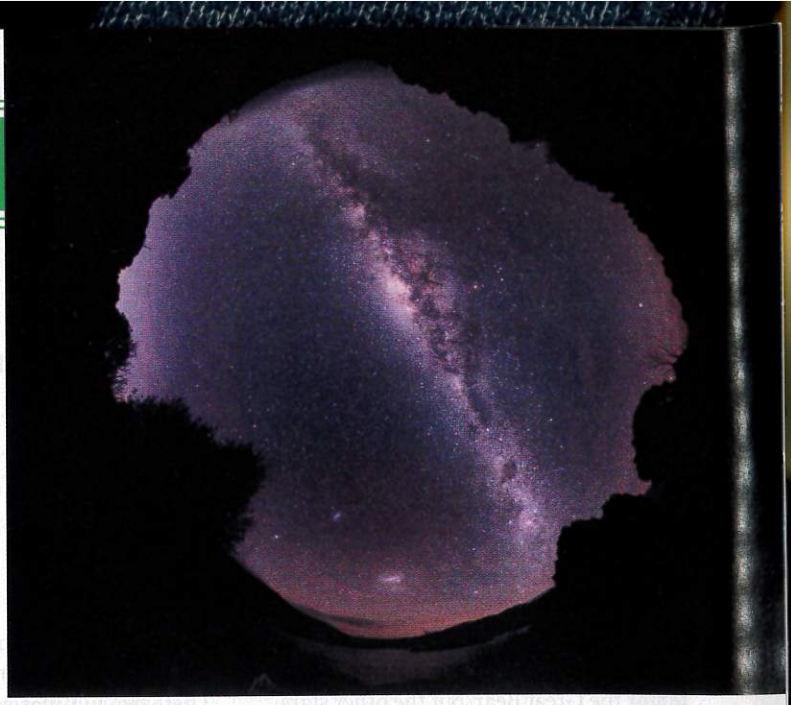
No one notices the sky changing from one night to the next. Yet any given star rises about four minutes earlier each evening due to Earth's orbital motion. Four minutes difference per day means that after a month, stars rise two hours earlier and set two hours sooner. Thus, constellations slowly drift westward throughout the year.

Wandering "stars"

Planets don't reappear regularly each season the way stars do because planets constantly orbit the Sun. Yet planets always lie somewhere along a band of constellations called the zodiac.

Two planets, Mercury and Venus, orbit closer to the Sun than Earth. You will see them only before sunrise or after sunset. Mercury in particular is hard to spot, being often low in the twilight. (Binoculars help.)

The outer planets (which lie farther from the Sun than Earth) move slowly among the stars, with changes becoming apparent only after a few weeks. Typically, they remain visible for months. Mars often appears bright and red. Jupiter, colored white, is always bright. Saturn, dimmer than Jupiter, looks yellow. The outermost planets — Uranus and Neptune — glow weakly and belong in binoculars territory.



The Milky Way glows above Te Waipounamu, the large southern island of New Zealand. To create this all-sky image, the photographer combined five 1-minute exposures. TUNÇ TEZEL

Far outshining any planet is the Moon, its face mottled with dark lava flows. The Moon circles Earth, keeping one side turned toward us. It first appears as a thin crescent in the evening sky. Night by night, the lit portion grows. The half-lit point is called First Quarter because the Moon has completed one-fourth of its monthly orbit. At Full Moon, it is completely lit and floods Earth with reflected sunlight. After Full Moon, the lit portion shrinks. When Last Quarter Moon arrives, we see it in daytime morning hours as well as after midnight. After passing Last Quarter, the Moon shrinks to a crescent visible shortly before sunrise. Then it reappears low in the west after sunset, and the cycle begins anew.

Be prepared

Star-watching is easy, but a few basic preparations make it comfortable. Depending on the season, you may want a coat and a ski cap — or insect repellent. Take a lawn chair and a thermos filled with hot cocoa or tea.

If you have binoculars, bring them along. But learning your way around the sky goes better if you start with no optical aid at all. Constellation patterns are easiest to find with the wide-field view your eyes alone can provide. The next four pages will introduce you to each season's sky.

COVER IMAGES: MATTIAS MALMER/CASSINI IMAGING TEAM (SATURN); ADAM BLOCK/MOUNT LEMMON SKYCENTER (SPIRAL GALAXY); NASA/GSFC/ASU (FULL MOON); MIGUEL CLARO (HORIZON SCENE WITH THREE AMATEUR ASTRONOMERS)

Explore the spring sky

Spring. Finally, it's warm enough for even thin-blooded observers to break out their binoculars and telescopes. If you're new to astronomy, however, you'll want to become familiar with the constellations and bright stars that populate this season's night sky before looking through the eyepiece. Then, when you read that a sky treat is in Boötes or near Regulus, you'll already have a frame of reference.

High in the northeast, the sky's most recognizable star pattern — the Big Dipper — is easy to spot after sunset. The Dipper is part of the third-largest constellation, **Ursa Major** the Great Bear, but the other stars are much fainter, so concentrating on the Big Dipper is the way to start.

Find the bend of the Dipper's handle. Sharp-eyed observers can see two stars in this space. Arabian astronomers 10 centuries ago called them the Horse and Rider.

The brighter of the two is **Mizar**, shining five times brighter than **Alcor**, which sits a bit to the east-northeast. This pair is an optical double, as in optical illusion. Mizar lies 78.2 light-years away while Alcor sits 81.2 light-years distant.

Because the Big Dipper is so easy to find, amateur astronomers use it to help them locate lots of constellations and stars in the spring sky. For example, use the Big Dipper's Pointer Stars, Dubhe and Merak, to find the most famous star in the sky: **Polaris**, the North Star. Draw a line from Merak to Dubhe, and extend that line five times the distance between those two stars.

Polaris, which lies roughly 430 light-years from Earth, marks the end of the Little Dipper's handle. Alternatively, it's the brightest star in **Ursa Minor** the Little Bear, and it marks the tip of the Bear's tail. Unlike the Big Dipper, however, most of the other six stars of the Little Dipper are faint. You'll need a dark location to see them all.

Head back to the Big Dipper, and locate its handle. Follow beyond the curve of the handle to two brilliant stars: **Arcturus** and **Spica**. These two luminaries illustrate some of the color differences between stars.

Arcturus appears copper-colored or orange, while Spica is bright blue. Stars have different colors because nuclear reactions in their cores heat their surfaces to different temperatures. Arcturus is a giant star with a relatively cool surface temperature of 7300° Fahrenheit (4040° Celsius).

Spica also is a giant, but it ranks among the hottest of stars. Its surface burns at 35,500° F (19,700° C). For comparison, the Sun lies in the middle of the temperature range. On its surface, a thermometer would read 10,300° F (5700° C).

Arcturus lies in the constellation **Boötes** the Herdsman some 37 light-years away. The star's name comes from a combination of terms that means "the Bear's guard," which signifies its position near Ursa Major the Great Bear. The main part of Boötes looks like a thin kite or an ice-cream cone.

Spica sits 260 light-years away in the southern reaches of **Virgo** the Maiden. This sprawling star group ranks second in size among the 88 constellations.

The constellation Leo the Lion combines a huge sickle (right) that's the Lion's head and a triangle of stars (left) that forms its hindquarters and tail. The brightest star is Regulus. BILL AND SALLY FLETCHER

Go back to the Big Dipper. To find our next constellation, poke a hole in the Dipper's bowl, let all the water run out, and wait for a loud roar. Mythologically, that's what you'll hear because the water fell on the back of **Leo** the Lion.

Leo's main figure has two parts: A backward question mark and a triangle. The question mark, or sickle-shaped figure, represents the front of the Lion. Dotting the question mark with a distinctive blue-white color is **Regulus**. Regulus lies 77 light-years from Earth.

East of the sickle, a right triangle marks the Lion's back and tail. The star farthest east of Regulus is **Denebola**. It lies 36 light-years away, about the same as Arcturus. A slightly brighter star than Denebola, **Algieba**, lies to the upper left of Regulus. Algieba is a spectacular orange and yellow double star 126 light-years distant. You'll have no difficulty seeing both components through a 3-inch telescope.

Some 20° (the width of two fists at arm's length) west of Leo's sickle lies one of the sky's faintest constellations, **Cancer** the Crab. At its center you'll find **M44**, the fabulous Beehive Cluster. Through 10x50 binoculars, most observers can count three dozen stars. The Beehive Cluster lies at a distance of about 580 light-years.

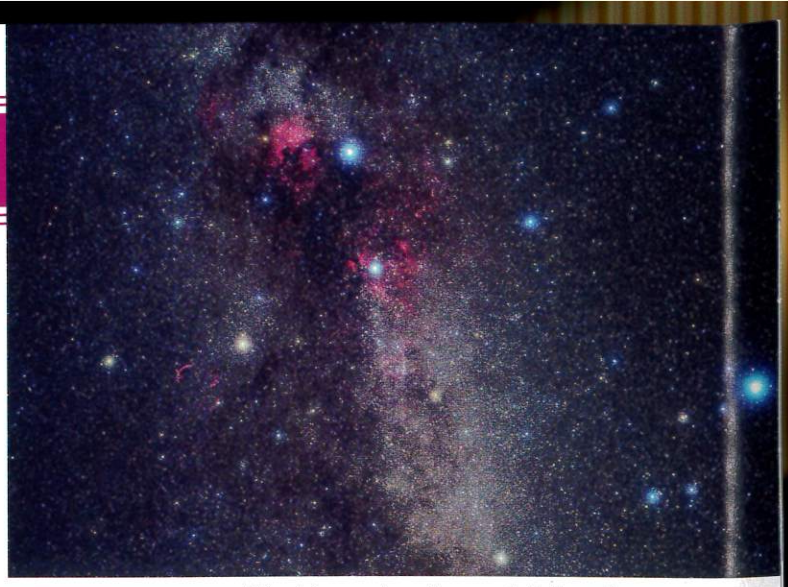
Below Virgo sits the small constellation **Corvus** the Crow. Its four moderately bright main stars and "crooked box" shape make it easy to find. There's another way to be sure you're looking at Corvus: See if its top two stars point upward to Spica.

Spring is an ideal time to start learning the sky. Many of the constellations are large, and helpful indicators like the Big Dipper lead you to the brightest stars. Before you know it, summer will dawn.

The Big Dipper (left) and the Little Dipper (right) are famous star patterns. Note how the Pointer Stars in the Big Dipper point toward Polaris, the North Star in the Little Dipper. BILL AND SALLY FLETCHER

The Beehive Cluster, also known as M44, is an easy target through binoculars. This object is a star cluster, a group of stars that formed together out of a large cloud of gas and dust. RICHARD MCCOY

Explore the summer sky



This picture captures two constellations. Cygnus the Swan dominates most of the image while Lyra the Harp lies at the lower right. Lyra's main star, blue-white Vega, shines brightly. BILL AND SALLY FLETCHER

If you want to begin observing the sky, start when it's warm. High in the northwest in the evening, seven stars form the Big Dipper. This well-known group daily circles the North Star, **Polaris**. The two stars at the end of the Dipper's bowl — the Pointer Stars — point to Polaris. The Big Dipper, however, is not a constellation. It's part of **Ursa Major** the Great Bear.

Use the curve of the Big Dipper's handle to lead you south to **Arcturus**, the brightest star in the constellation **Boötes** the Herdsman. Arcturus glows orange, indicating it's a cool star. It ranks as the fourth-brightest nighttime star and the brightest in the northern half of the sky.

Overhead, three bright stars form summer's second-easiest star picture (next to the Big Dipper) — the Summer Triangle. Each is the brightest star in its constellation. The brightest is **Vega** in **Lyra** the Harp; next brightest is **Altair** in **Aquila** the Eagle; and the third is **Deneb**, the star marking the tail of **Cygnus** the Swan.

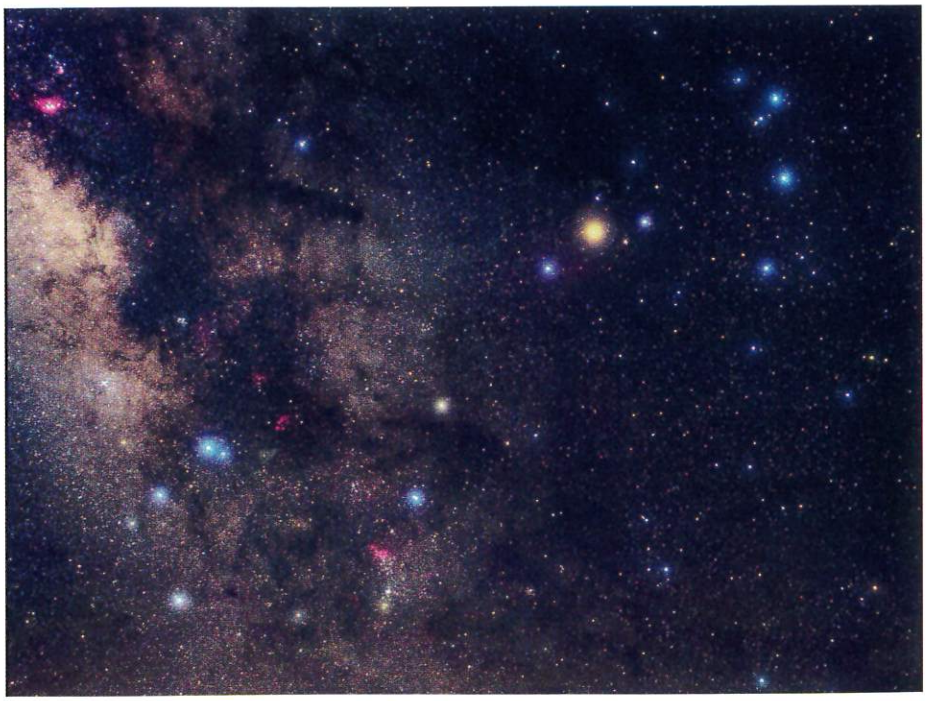
Cygnus contains the asterism (a recognizable star group that's not a constellation) of the Northern Cross. **Albireo** lies at the base of the cross. This object is one of the top 10 showpieces for small telescopes. Albireo is a colorful double star, wide enough that even 10x50 binoculars will separate the pair. Color perception is unique among humans, but most observers see these stars as gold and sapphire-blue.

Try finding the **Coathanger** asterism through your binoculars. About halfway between Albireo and Altair, the Coathanger is a line of six stars with a curve of four stars (the hook) protruding from its center.

A bit west of the Summer Triangle lies **Hercules**, the legendary hero. This constellation contains one of amateur astronomy's main tourist sights — the Hercules Cluster (**M13**), the finest globular star cluster in the northern sky. M13 lies along one side of the Keystone, a crooked box of four medium-bright stars that mark the Hero's body.

You'll find the Keystone about two-thirds of the way from Arcturus to Vega. You can glimpse M13 with your unaided eyes under a dark sky, but it looks better through binoculars, where it will appear half the width of the Full Moon.

The "M" before the number 13 stands for "Messier object." French comet-hunter Charles Messier (1730–1817) compiled a list of 109 such objects. When observers looked through the small telescopes of Messier's day, such objects resembled comets. He wanted other observers to realize they weren't comets. Through today's scopes, however, Messier's list contains many of the finest celestial targets.



The constellation Scorpius the Scorpion is one of the few star patterns that looks like its namesake. It lies in the direction of the center of the Milky Way, so we see a lot more stars in this area. BILL AND SALLY FLETCHER

Now head far to the south from Hercules to **Scorpius** the Scorpion. Because Scorpius and neighboring Sagittarius lie in the southern part of the sky, thick air layers dim their glory from northern latitudes. Everyone should be able to find **Antares**, the bright star marking the Scorpion's heart. Antares is a red supergiant 400 times larger than the Sun.

Next to the Scorpion's stinger lie two glorious open star clusters, **M6** and **M7.** M6, popularly known as the Butterfly Cluster because of its shape, appears slightly elliptical, and its brightest star is an orange giant that varies in brightness.

M7 is easy to spot with your naked eyes as a bright knot in the southern Milky Way. Through binoculars, M7 appears more than twice as wide as the Full Moon. M7's central stars are arranged in an X while the outliers form a triangle.

East of Scorpius lies **Sagittarius** the Archer, whose central part resembles a teapot. When we look at this star pattern, we're looking toward the center of our galaxy. Many more stars lie in this region than anywhere else in the sky. The area also has a large amount of gas and dust, however, which dims the stars' light. That's why the area isn't overwhelmingly bright.

Once you learn the main constellations and bright stars in the summer sky, you'll find lots of excuses to be out at night during this season. In fact, you'll probably have so much fun that you won't even notice fall's chillier air all that much.

Explore the fall sky

Cassiopeia the Queen is a fall constellation with an easily identified shape. It looks like the letter W. Or, if you see it on the other side of the sky, it looks like the letter M. BILL AND SALLY FLETCHER

Fall is a great time for stargazing. Evenings arrive more quickly than in the summer, and all the stress from traveling or getting the kids ready for school lies in the past. And although the fall sky may not contain the most brilliant stars, great targets abound. The Milky Way arches from the northeast to the southwest, and it contains countless wonders. Set up a reclining chair at a dark site, and scan our galaxy's spiral arms with just your eyes or through binoculars. You'll be glad you did.

Let's start our tour high overhead. As the glow of sunset wanes, you'll spot the three bright stars that form the Summer Triangle: **Vega** in **Lyra** the Harp, **Altair** in **Aquila** the Eagle, and **Deneb** in **Cygnus** the Swan. Deneb marks the tail of the Swan, and **Albireo** is its head. Albireo makes a terrific small-telescope target: a double star that glows gold and blue.

But the Summer Triangle isn't the only geometric figure you'll find in the fall sky. Look east of the Summer Triangle for four stars that form the main part of the constellation **Pegasus** the Winged Horse. Astronomers call this stellar quartet the Great Square, and it's the easiest way to find the legendary horse. Pegasus is a huge constellation that spreads out toward the west from the Great Square.

From a dark site, point binoculars or a telescope about four binocular fields of view west of the star at the Great Square's southwest corner. There, you'll find a globular cluster (a spherical grouping of tens of thousands of stars) named **M15**.

The northeast star of the Great Square doesn't belong to Pegasus. It's Alpheratz, the brightest star in **Andromeda** the Princess, which appears as two lines of stars that start at Alpheratz and curve northeast.

Follow the northern curve for two stars and then go right one star. Look about half a binocular field northwest, and you'll spot the Andromeda Galaxy (**M31**), the northern sky's greatest galaxy. You can see it without optical aid from a dark site, where it will appear as a faint piece of the Milky Way that broke off. But it's not part of our galaxy. Rather, it's a separate system that numbers nearly half a trillion stars. That many stars give off an incredible amount of light, but M31 still appears faint because of its distance. Although M31 is one of the nearest galaxies to us, it lies some 2.5 million light-years away.

Just north of Andromeda, look for the bright constellation **Cassiopeia** the Queen. Depending on the time of night, the five luminaries of this star group will appear either as the letter W or M. Cassiopeia lies smack-dab in the Milky Way, so it's full of tightly packed star clusters you can spot through binoculars.

The W of Cassiopeia opens toward the north and the constellation **Cepheus** the King. Search for five stars that look like a pencil sketch of a house.

Cepheus lies midway between Cassiopeia's W and **Polaris**, the North Star. Polaris ranks as the sky's 47th-brightest star, which is still pretty bright.

Next, return to Cassiopeia's W figure. Use binoculars to search two binocular fields of view east of Cassiopeia for the Double Cluster (**NGC 869 and NGC 884**), which lies just above the head of the constellation **Perseus** the Hero. Although you can spot both clusters as fuzzy objects with your eyes, binoculars bring out their best.

Just beyond Perseus' other end lies the fall sky's best naked-eye/binocular deep-sky object: the Pleiades (**M45**). Early in the fall, M45 doesn't rise until several hours after sunset, but it's worth the wait. With your naked eyes, you can see six Pleiads in the form of a tiny dipper. It's not the Little Dipper, however, which is in the north.

Through binoculars, three dozen stars will dazzle you. For M45, a magnification between 10 and 15 times works best. If possible, mount your binoculars on a tripod because high-power units tend to weigh more, and your arms will fatigue long before you get tired of the view.

Once you learn the bright stars and constellations in the fall sky, it will be easy for you to transition to the other three seasons. In a short time, you'll be locating lots of great celestial objects to enjoy alone or to share with others.

The Pleiades, also known as M45, is the brightest of all star clusters. You'll see six or seven stars with just your eyes, three dozen through binoculars, and more than 100 through a telescope. ANTHONY AYIOMAMITIS

Explore the winter sky

The winter sky offers the brightest stars of any season. This makes finding the constellations that contain them easy. At this time of year, the Milky Way arches from north to south. Along that path, deep-sky treasures visible through binoculars abound. All you need is this article and a way to stay warm.

Toward the south, look for the magnificent constellation **Orion** the Hunter. Orion looks like a giant butterfly, with the three stars of his Belt marking the butterfly's body and wings to either side.

Orion's brightest star is **Rigel**. It marks his left knee (the one to the bottom right, as we see it in the sky).

To Rigel's upper left, past Orion's Belt, lies **Betelgeuse**. Although modern descriptions list Betelgeuse as one of Orion's shoulders, the original Arabic name more closely means "the armpit of the mighty one."

As you view Rigel and Betelgeuse in the sky, you'll notice they have quite different colors: Rigel is bright blue, and Betelgeuse shines with a coppery tone. Stars shine with different colors because their surfaces radiate at different temperatures. Blue stars typically have surface temperatures above 20,000° F (11,000° C). The surface of a red star like Betelgeuse heats the thermometer to only 3000° F (1650° C).

In the region of Orion's Sword, which hangs below his Belt, sharp-eyed observers will see the area as slightly fuzzy. This is the Orion Nebula (**M42**) — a huge star-forming region. Binoculars improve the view, but the view through a small telescope with an eyepiece that gives a magnification of about 100x is best.

The Orion Nebula, also known as M42, is a vast cloud of dust and gas where stars are forming. The cloud glows because radiation from stars energizes the atoms within it. TONY HALLAS

Because Orion is so easy to find, you can use it as a starting point to locate many other stars and constellations. For example, if you draw a line down to the southeast from Orion's Belt, you'll arrive at **Sirius**, the night sky's brightest star. Because of its position in **Canis Major** the Big Dog, the ancient Greeks referred to Sirius as the Dog Star.

Point your binoculars at Sirius, and move the star so it sits at the top of the field of view. Near the center, you'll see a faint, fuzzy patch of light that looks like a cotton ball. That's open star cluster **M41**. Open clusters are loose collections of dozens to hundreds of stars that formed at the same time. Few open clusters are old because their stars disperse due to gravitational interactions within the clusters.

Canis Major isn't Orion's only canine companion — there's also **Canis Minor** the Little Dog. To find it, make an equilateral triangle using Betelgeuse, Sirius, and Canis Minor's brightest star, **Procyon.** These three stars form an asterism (a recognizable star pattern that's not a constellation) called the Winter Triangle. Once you find Procyon, draw a line northwest to the star Gomeisa, and you've outlined the little dog — just two stars!

Now draw a line from Orion's Belt in the opposite direction. You'll soon come to a V-shaped group of stars called the **Hyades**, which marks the head of **Taurus** the Bull. Taurus' eye is the ruddy star **Aldebaran**.

Continue the line upward, and you'll hit the Pleiades (**M45**). This naked-eye star cluster (sometimes called the Seven Sisters) appears best through 10x to 15x binoculars. Telescopes tend to magnify the cluster too much, spreading out the stars and reducing the number of them that you'll see at once.

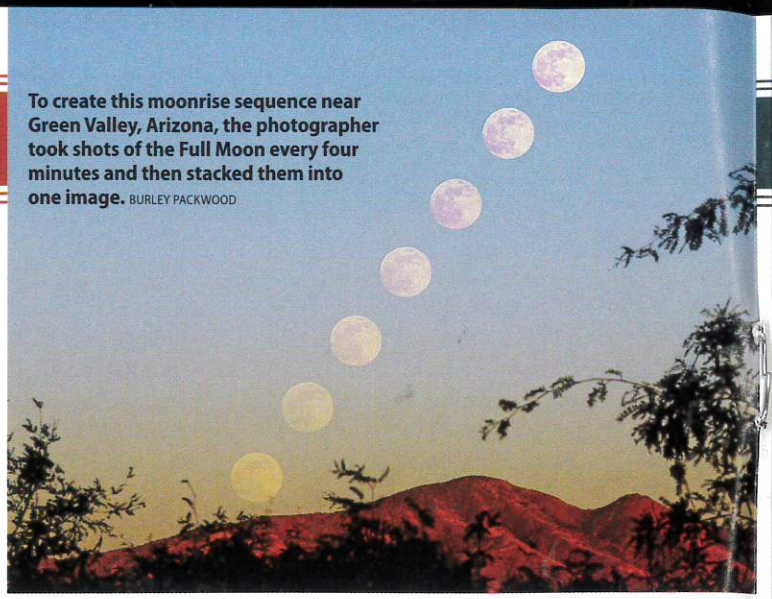
The constellation Orion the Hunter dominates the winter sky. Notice how the copper hue of the star Betelgeuse makes it stand out among the mostly blue suns in this group. BILL AND SALLY FLETCHER

If you extend a line straight up through Orion's body and head, you'll find the constellation **Auriga** the Charioteer. The brightest star in this pattern is yellow **Capella**. Capella is a word that means "mother goat," and early observers called the triangle of faint stars just to the southwest of Capella the "Kids."

Return to Orion one last time. Draw a line from Rigel to Betelgeuse. Continue the line about 1½ times that distance to find **Gemini** the Twins. The two stars marking the Twins' heads are **Castor** and **Pollux**. An easy way to tell which is which is to remember a bright star first-letter match: Castor lies closer to Capella, and Pollux is on the same side as Procyon.

Learning the major constellations and bright stars in the winter sky is easy, even from a brightly lit backyard. And if you chill quickly, just five or 10 minutes a night will do it. In a short time, you'll be the astronomy expert in your group of friends. And you won't even need a star map.

10 tips for Moon watchers



To create this moonrise sequence near Green Valley, Arizona, the photographer took shots of the Full Moon every four minutes and then stacked them into one image. BURLEY PACKWOOD

The Moon offers something for everyone. It's visible most nights, its ever-changing face has features one night not seen the previous night, and it doesn't take an expensive setup to enjoy it. To help you get the most out of viewing the Moon, follow these 10 tips, and you'll be on your way to a lifetime of lunar observing.

To start, don't use optics

The best way to begin your journey as a lunar observer is to learn the Moon's major features. Head out with a simple Moon map, and use just your eyes to identify our only natural satellite's top attributes. Once you know a few, you can add binoculars.

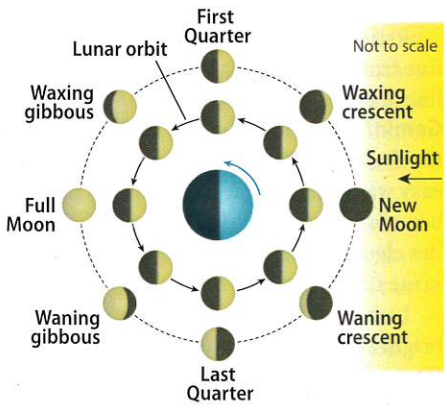
The Full Moon is bright

Contrary to what you might think, Full Moon is not the best time to observe our natural satellite. When the Moon is Full, the Sun lies behind Earth (as we face the Moon), shining directly down on the lunar surface. Shadows are at their minimum lengths, so you can't see much detail.

View at "prime time"

Two intervals during the lunar "month" (from one New Moon to the next) are best for observers. The first begins shortly after New Moon and continues until two days past First Quarter. On these days, the Moon lies in the evening sky.

An equally good observing period starts about two days before Last Quarter and ends when the Moon lies so close to the Sun that it's lost in morning twilight. During both intervals, shadows are longer and features stand out in sharp relief.



This graphic shows the phases of the Moon as we see them from Earth (outer circle of Moons) and also how the Sun illuminates our satellite (inner circle). *ASTRONOMY:* ROEN KELLY

The terminator is great

During the two prime-time periods, aim your scope along the line that divides the Moon's light and dark parts. Astronomers call this line the terminator. It's where sunrise (or sunset) is happening.

You'll see the tops of mountains protruding just high enough to catch the Sun's light while surrounded by lower terrain that remains in shadow. Features along the terminator change in real time, and during a night's observing, the differences you'll see through your telescope are striking.

The best Moon scope?

Nearly any telescope will do to observe lunar details. Observers with several options (but not a permanent observatory) usually pick a scope they can set up many nights in a row. Observing on successive nights makes it easier to follow the terminator's progress.

Cut down the moonlight

Many observers use either neutral density filters or variable polarizing filters to reduce the Moon's light. The latter lets you change how much light the filter transmits.

Two other methods to reduce the Moon's brightness are high magnification and an aperture mask. High powers restrict the field of view, thereby reducing light throughput. An aperture mask causes your telescope to act like a much smaller instrument, but at the same focal length.

Turn on your best vision

Some years ago, an observer found a better way of observing the Moon: Turn on a white light behind you when you observe between Quarter and Full phases. The light should be moderately bright (in the 60-watt range), but neither your eyes nor the eyepiece should be in direct view of the fixture.

The addition of white light suppresses the eyes' tendency to dark adapt at night. Not dark adapting causes the eye to use normal daytime vision, which is of higher quality than dark-adapted night vision. So, you'll see more detail because you're viewing with a better part of your eye.

Work from a list

A great way to learn the Moon is to undertake an observing project. In the United States, the Astronomical League offers one such project, the Lunar Observing Club. You'll learn a lot about our satellite as you work through a list of 100 lunar features.

To receive a certificate, you must be a member of the league, either individually or through an astronomy club. For details about the club, see www.astroleague.org/al/obsclubs/lunar/lunar1.html.

Dig for the details

Of the 1,940 named lunar features, 1,545 are craters. Challenge yourself to see either how small a crater you can detect or how many you can observe in a given area. You'll need a Moon map for this project.

For the second challenge, you can choose a lunar sea, but usually a large, flat-bottomed crater works best. For example, if you search the large crater Plato, you'll find four small craters on its floor. Lunar observers consider seeing these craters a test for a 6-inch telescope.

Shoot the Moon

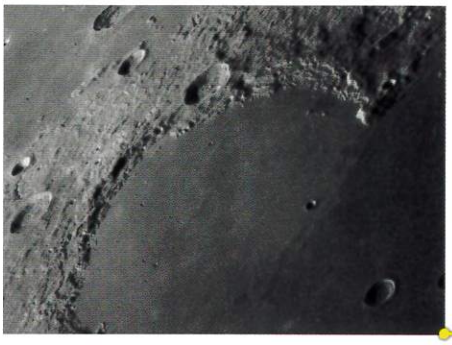
How can a celestial object that's so easy to photograph be so difficult to photograph well? The Moon is large and bright, and you can use any camera connected to any size telescope to image it. That's the easy part.

But the Moon also contains vast areas of low contrast that have little color differential. Recording those regions so they look like what your eyes see is the hard part.

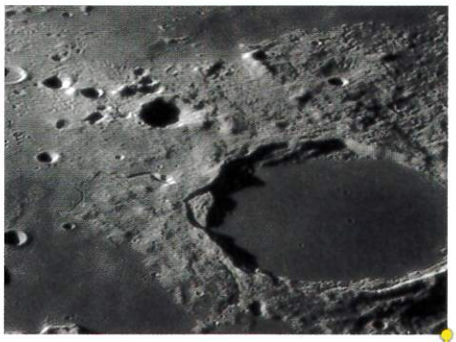
Luckily, we live in the digital age. It costs nothing extra to take 200 images instead of just one. Examine them, delete what you don't like, change one or more parameters (including the techniques you used to process the images) each time, and shoot some more as you perfect your techniques.

Explore 8 lunar targets

Plotted here are the locations of eight easy-to-observe lunar features. Just point your telescope at the spot shown on the Moon map, and you're on your way to observing our satellite. North is up in all images. FULL MOON IMAGE BY LICK OBSERVATORY

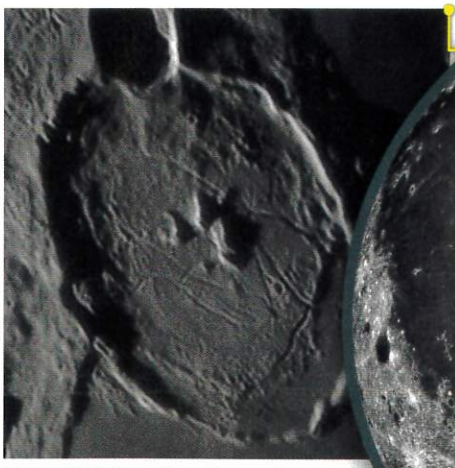


Sinus Iridum, the Bay of Rainbows, on the Moon's northwestern edge spans a whopping 162 miles (260 kilometers). Numerous tiny craters dot Sinus Iridum's remarkably flat surface. The Jura Mountains form its curved edge. ALAN FRIEDMAN

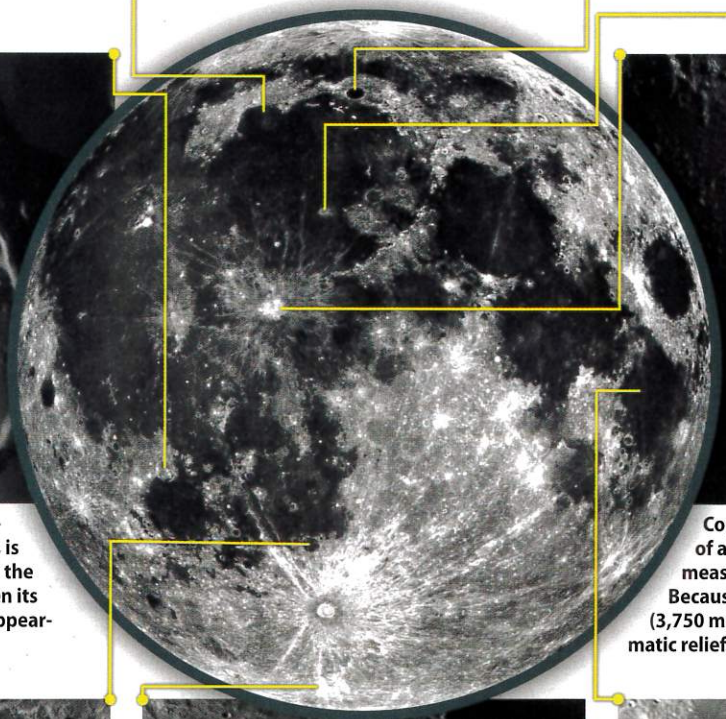


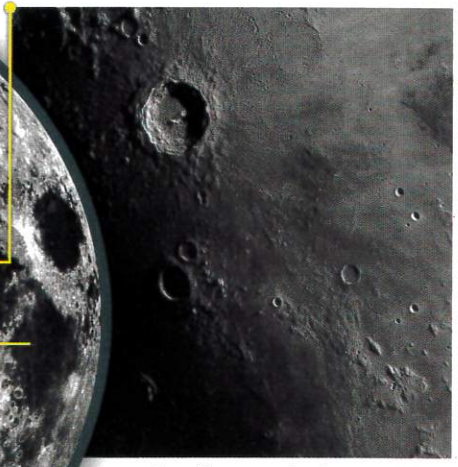
Plato Crater lies at the Moon's top center. It spans 63 miles (101 kilometers) and has one of the darkest crater floors on the Moon. Polish astronomer Johannes Hevelius called Plato the Greater Black Lake. ALAN FRIEDMAN

Archimedes Crater lies at 30° north latitude centered between the eastern and western limbs. This 52-mile-wide (83 kilometers) impact crater lies just northwest of the Moon's largest mountain range, the Montes Apenninus. ALAN FRIEDMAN

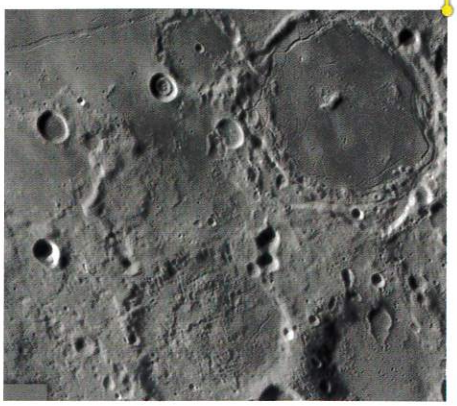


Gassendi Crater, whose long axis measures 68 miles (110 kilometers) across, is a spot that will hold your attention. To the north, the crater Gassendi A has broken its wall. Together, both craters give the appearance of a diamond ring. ALAN FRIEDMAN





Copernicus Crater marks the center of a system of bright rays. Copernicus measures 58 miles (93 kilometers) wide. Because of its great depth — 12,300 feet (3,750 meters) — shadows here create dramatic relief. PAOLO LAZZAROTTI



Pitatus Crater (upper right), which spans 60 miles (100 kilometers), contains features strewn about its floor. A low central peak sits just to the northwest of the crater's center. With a medium-sized telescope and a magnification of about 100x, you'll spot a system of clefts across the lava-filled floor. The feature with double walls to the left of Pitatus is Hesiodus Crater. ALAN FRIEDMAN

Clavius Crater ranks as the third-largest crater on the Moon's nearside. It spans 140 miles (225 kilometers). But it's what's in Clavius that's cool. Look for the curving crater chain of decreasing size that begins at Clavius' eastern (right) wall. The largest is Rutherford Crater, then Clavius D, Clavius C, Clavius N, and Clavius J. Porter Crater breaks Clavius' wall to the upper right. DAVID TYLER

Messier and Messier A are two small but well-known craters that sit on the Moon's eastern side only 2° south of its equator. Messier is an oblong crater measuring 5.6 by 6.8 miles (9 by 11 kilometers). Messier A spans 8.1 by 6.8 miles (13 by 11 km). Two linear rays (splashes of material from impacts) extend westward from Messier A for more than 60 miles (100km). ANTHONY AYIOMAMITIS

Beyond the Moon

All the planets are fair game for backyard telescopes — even distant Pluto. But the most popular are Jupiter, Saturn, and Mars because they show the most features.

Jupiter spins in less than 10 hours, so the vista changes all the time. What looks like a cloud-striped surface on Jupiter is the top of a deep hydrogen atmosphere churned by heat from below. Spots and markings appear, last for months or years, then merge and disappear. The Great Red Spot, twice the size of Earth, has lingered for more than 350 years. Jupiter-watchers monitor the planet for changes and alert scientists when they occur.

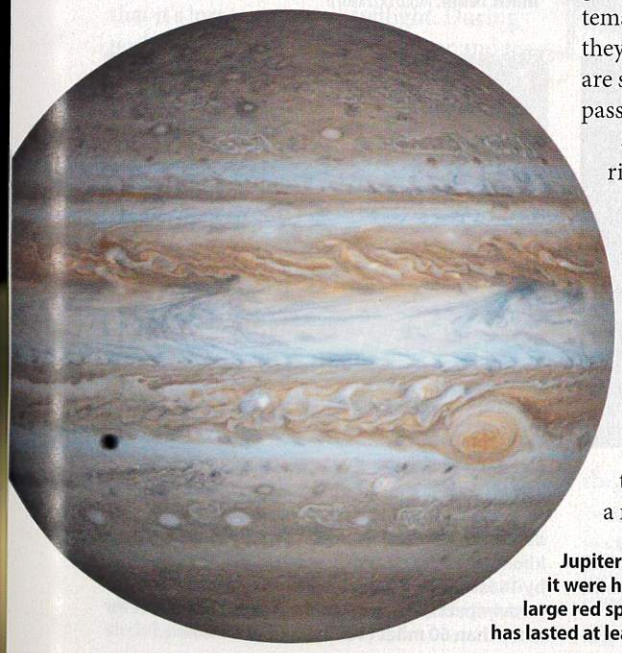
Around Jupiter, a family of moons swirls like a miniature solar system. Galileo discovered the biggest four, which you can easily follow in any size telescope. (See the monthly illustration in *Astronomy*.)

Saturn is a smaller, lighter, cooler Jupiter, so its cloud bands are less pronounced — but the prominent ring system makes a world of difference. Saturn never fails to elicit a gasp when people see it for the first time. You'll want to look at its jewel-like beauty all night long.

The Red Planet

No one has yet stood on the sands of Mars, but you can peer into a backyard telescope and sometimes see hazy clouds over its large volcanoes. Occasionally, dust storms gather to veil parts of Mars — or all of it. Polar caps grow and shrink as seasons pass.

Mars is a challenging world to observe from Earth because of its small size and varying distance — it's close to Earth for only two months out of 26. Yet, in many ways, Mars is our most Earth-like neighbor. This exerts an irresistible pull on every backyard telescope owner.



Jupiter is the largest planet in our solar system. If it were hollow, it could hold some 1,300 Earths. The large red spot is a storm twice as large as our planet that has lasted at least 350 years. NASA/JPL/UNIV. OF ARIZONA

The Sun

Before leaving the solar system, take a look at its central star — the Sun. Solar viewing requires a special solar filter that fits over the front of the telescope — never use an eyepiece solar filter. A front-mounted solar filter lets you safely view features such as sunspots, which are relatively cool and dark regions far bigger than Earth. They occur where the Sun's magnetic field becomes knotted and hinders the flow of internal heat. For reasons no one yet understands, sunspot numbers wax and wane over an 11-year cycle.

The starry sky

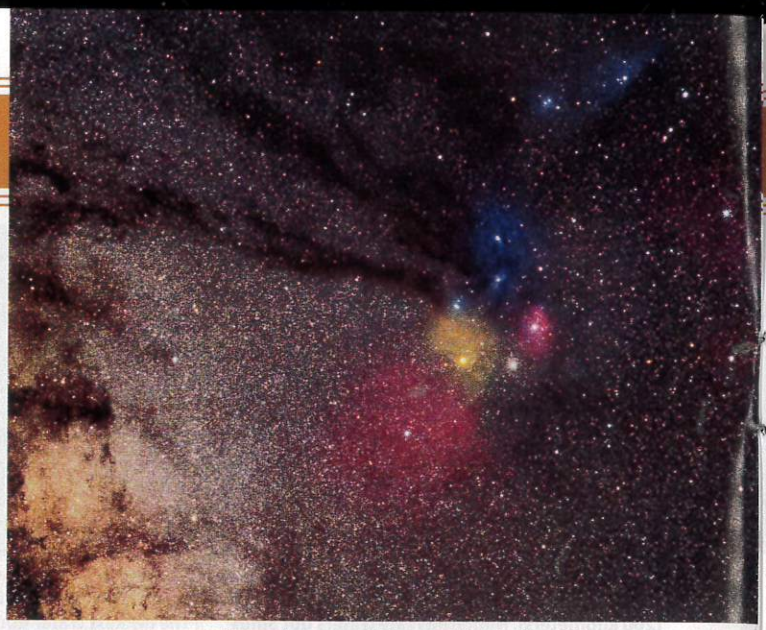
Scanning the sky — and particularly the Milky Way — with a telescope, you find stars in pairs and triplets. Some are chance groupings, but most are real multi-star systems, locked together by gravity. While they orbit at high speeds, their distances are so great that decades or centuries will pass before changes become apparent.

Stars also gather in clusters — tight, rich groups that stand out from the background. Open clusters contain a few dozen to a few thousand members. The Pleiades (M45) in Taurus is a beautiful open cluster, more populous and less scattered than its neighbor, the Hyades.

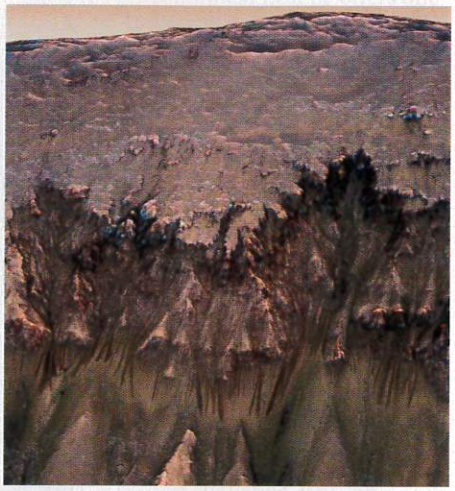
Stars also group together as globular clusters. If open clusters are like small towns, globulars are cities, containing tens of thousands to upward of a million stars each. When you look at a globular through a telescope, you see a bright center sprinkled with stars that run outward until the blackness of space takes over. A globular cluster looks like a tiny pile of sugar dropped on black velvet.

The best place to look for open clusters is along the Milky Way, but globulars are usually found flanking it. The region of sky richest in globular clusters lies in Scorpius and Sagittarius, best seen in summer. But a superb globular, M13, lies in spring's Hercules, where it shines bright enough to see by eye from a dark observing site.

Star clusters are born from vast clouds of dust and gas that occur throughout the Milky Way. Astronomers call such clouds nebulae, and they make favorite targets for telescope users. A nebula looks like a soft haze through the eyepiece. Irregular in shape, many nebulae contain an open star



The region around the star Rho Ophiuchi is one of the most colorful in the sky. And because it's near the center of our galaxy, this area also is one packed with billions of stars. TONY HALLAS



These dark streaks on Mars may be the result of flowing — but quickly evaporating — water. The streaks only appear during the martian spring and summer. HIRISE/MRO/LPL (UNIV. OF ARIZONA)/NASA

The Fireworks Galaxy, also known as NGC 6946, got its name after eight supernovae exploded there in the past century. It lies in the constellation Cepheus. ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA

cluster, born from the nebula perhaps in the last few million years. A famous example is the Orion Nebula (M42).

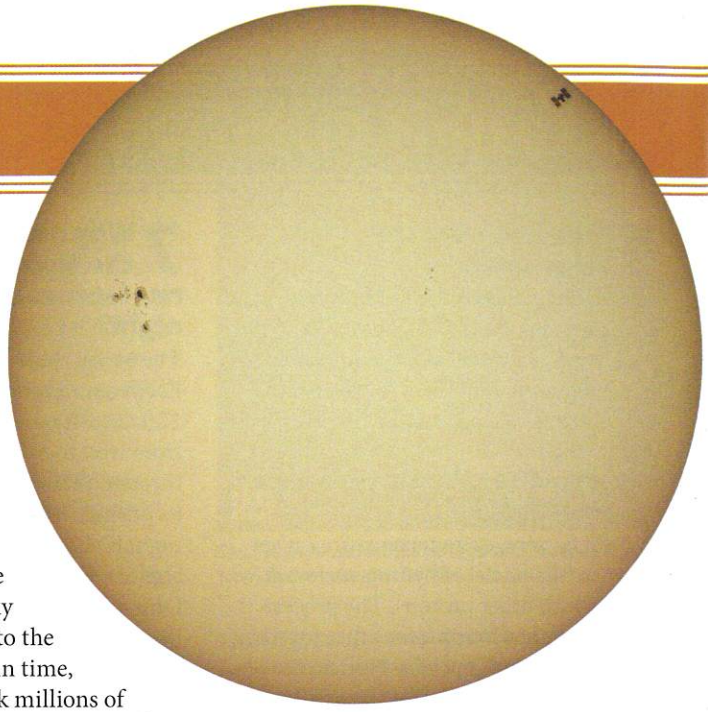
Another kind of nebula is the planetary nebula, so called because through small telescopes many resemble Neptune. A planetary nebula represents the end of a star's life. As Sun-like stars age, they blow off shells of gas around their hot cores. The shells expand and fade, and the cores cool.

Not all stars die quietly, however. The Crab Nebula (M1) in Taurus marks where a star exploded about 1,000 years ago. The remnant is expanding, shooting gaseous debris back into space, where much of it will wind up in a new generation of stars.

Realms of infinity

You can take your first step beyond the Milky Way just by using your naked eyes. A dark autumn night shows the Andromeda Galaxy (M31) as a pale smudge of light near the Great Square of Pegasus. M31 lies 2.5 million light-years away. And the Andromeda Galaxy is just the start; beyond lies a realm of galaxies you can spend the rest of your life discovering.

Nereus Crater on Mars was the site of a meteorite impact years ago. It measures 30 feet (9.1 meters) in diameter. KENNETH KREMER/NASA/JPL/CORNELL/SPACEFLIGHT NOW



Our Sun is a star like the stars we see in the night sky. The biggest difference between it and them is that the Sun lies much closer to Earth. Note the International Space Station crossing at the upper right. ALAN FRIEDMAN

Backyard astronomers who prowl for galaxies are the deepest of the deep-sky explorers. As they peer into the telescope, they look back in time, deciphering light that took millions of years to arrive.

Quirks of geometry present some galaxies edge-on, like pencil beams of light. Some have ragged edges. Others, tipped face-on, tantalize us with spiral arms that hover on the edge of invisibility. A few galaxies show dark smudges like black eyes, where dust lies thick and the star-making factories are running day and night.

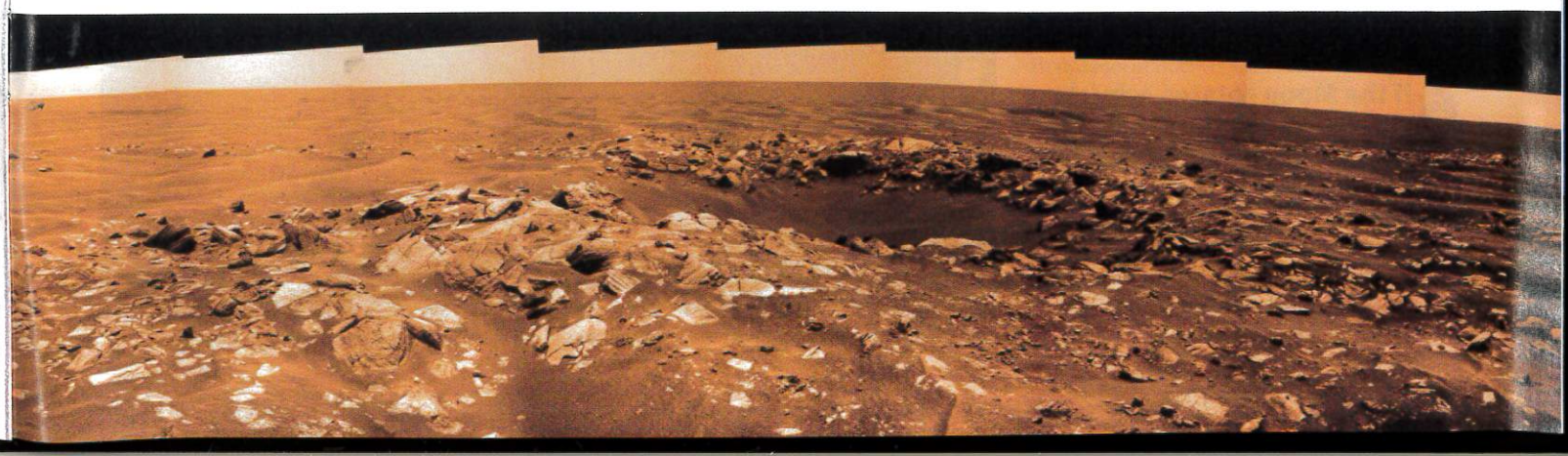
The Milky Way and Andromeda galaxies both belong to the Local Group, a cluster of some 50 galaxies. Nearby in Virgo lies a much larger galaxy cluster, one of many millions that shape the framework of the universe. Backyard astronomers can explore this realm in part — but even the pros haven't sounded its depths.

Of space and time

When we turn from the realm of the galaxies and look homeward, distances shrink, and the light our telescopes receive grows younger. Globular clusters appear as they were perhaps 20,000 to 50,000 years ago. And star clusters like the Pleiades shine as they were hundreds to thousands of years ago. Light from the nearest star — Alpha Centauri — takes 4.3 years to crawl from there to here. Pluto orbits some 5 light-hours away from the Sun, while Earth zips around just 8 light-minutes from the Sun.

47 Tucanae is a grouping of hundreds of thousands of stars called a globular cluster because of its round shape. This one is visible to the naked eye from a dark site at latitudes south of the U.S. FRED HERRMANN

And what about moonlight? It's reflected sunlight that left the Moon's dusty surface just 1.3 seconds ago. When you look through a telescope, you get more than a spaceship of the imagination — you get a time machine, too.



30 cosmic questions

1 Who invented the telescope?

Historians attribute this invention to Dutch spectacle maker Hans Lipperhey in 1608. Italian astronomer Galileo Galilei made telescopes and used them to observe the heavens beginning the following year.

2 How does the Sun produce energy?

Within its core, extreme pressure causes protons (the nuclei of hydrogen atoms) to collide with other protons. The process continues until four protons fuse together, creating a helium nucleus. Nuclear "fusion" releases enough energy for the Sun to shine.

Sunspots in active region 11164 appear dark in contrast to the rest of the Sun's surface. DAVE GRADWELL

3 Why are sunspots dark?

Actually, they're not. They just appear dark by contrast. Sunspot regions measure between about 2000° and 4500° Fahrenheit (1100° and 2500° Celsius) cooler than the surrounding surface.

4 How much of the Sun's energy does Earth receive?

Approximately two-billionths.

5 What is Universal Time?

It is a measure of mean solar (clock) time at 0° longitude. Astronomers use Universal Time — usually abbreviated UT — to standardize the times of celestial events and observations made by observers around the world.

6 If the Moon rotates, why do we always see the same side?

The long-term effect of tides between Earth and the Moon has locked our satellite's spin. That is, the Moon now rotates on its axis in the same time that it takes to revolve around Earth. Enough irregularities in the Moon's rotation exist, however, that we see 59 percent of its surface.

7 Why does the Moon rise later each night?

The Moon orbits Earth once every 27.3 days. It moves from west to east through the sky, so its position on any night is about 12° east of where it stood the previous night. On average, therefore, it rises 50 minutes later from one night to the next.

8 How are planets different from stars?

Planets do not generate their own light, although large planets like Jupiter may radiate some infrared and radio energy. Planets also are much smaller and less massive than stars.

9 Why is Mars called the Red Planet?

The color comes from the large amount of iron oxide (Fe_2O_3) — known commonly on Earth as hematite (or rust) — on the planet's surface.

10 Who discovered Jupiter's four large moons?

Italian astronomer Galileo Galilei found three of them (Io, Europa, and Callisto) January 7, 1610. On January 13, he observed the fourth one, Ganymede. Initially, he thought they were stars, but their motions during the next several weeks convinced him that they orbited the planet.

11 What process created Saturn's rings?

Long ago, the orbit of one of the ringed planet's moons decayed until it reached a distance where tidal forces from Saturn tore it into trillions of separate particles that still orbited the planet. The gravity of Saturn's moons then divided the system into rings.

Comets are small ice balls that glow and form tails as they approach the Sun. GERALD RHEMANN

12 What causes a meteor shower?

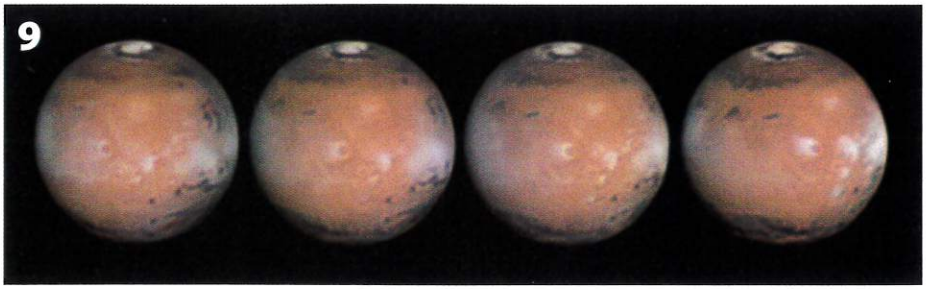
As a comet approaches the Sun, solar radiation boils away the comet's ice, releasing dust particles trapped within. If Earth's orbit intersects that of the comet, the particles enter our atmosphere at high speeds, creating a meteor shower.

13 Where do comets come from?

Short-period comets (those that orbit in less than 200 years) originate in our solar system's Kuiper Belt or in the scattered disk, both of which lie outside Neptune's orbit. Long-period comets come from the Oort Cloud, a sphere of icy bodies that stretches nearly 1 light-year from the Sun.

14 Why do comet tails point away from the Sun?

The reason is that radiation and the solar wind literally push the tail outward. Comets have two types of tail: ion (made of gases) and dust. The solar wind makes the ion tail straight in the direction opposite the Sun. Radiation pressure pushes the dust tail out, but it curves because its more massive particles fall behind the comet, moving into slower orbits.



Despite its odd reddish coloring, Mars is the planet in our solar system most like Earth. DAMIAN PEACH

15 When were the current constellations established?

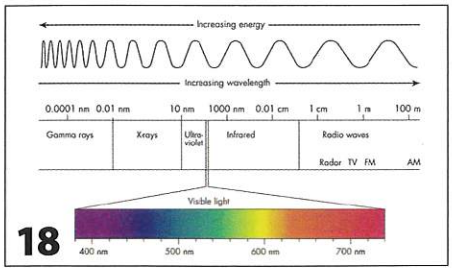
In 1928. Prior to that date, celestial mapmakers were free to populate star charts with as many or as few constellations as they desired. Today, 88 stellar figures cover the sky. No gaps exist between them, none overlap, and only one — Serpens — has two parts. This formal list arose out of a commission established by the International Astronomical Union in 1922.

16 Why do stars twinkle?

They don't. Stars appear to twinkle because they are points of light (not disks like planets) and because their light passes through our atmosphere. Layers of air act like moving lenses, which bend the light rapidly in alternating directions. The air layers also may act like a prism, causing a star's light to change color as it twinkles.

17 What creates the glow of the Milky Way?

This subtle nighttime radiance visible from dark sites represents the combined light of billions of stars along our galaxy's plane. Unfortunately, they're too distant for our eyes to resolve as points, so their light combines to create a glow.



The spectrum gives researchers lots of information about celestial objects. *ASTRONOMY:* ROEN KELLY

18 How do astronomers analyze light from celestial objects?

They disperse the light into a spectrum, an electronic plot that shows the relative strengths of each of the colors, which astronomers call wavelengths. By comparing a star's spectrum to one created in a laboratory, astronomers can deduce the percentages of all the elements the star contains. A star's spectrum also can tell scientists how hot the star is, how fast it is moving toward or away from us, whether it has a strong magnetic field, and more.

19 Do eclipses occur in a regular series?

Yes. Astronomers call it the Saros cycle, and it's approximately 18 years and 11⅓ days long. One cycle after any eclipse, the Sun, the Moon, and Earth will have the same geometry and a similar eclipse will occur.

20 What causes the Moon's colors during total lunar eclipses?

Earth's blanket of air scatters some sunlight onto its surface. A totally eclipsed Moon may appear yellow-white, orange, copper, rust, reddish-brown, brick red, gray, or nearly black. The color depends on the amount of dust and clouds in our atmosphere at the time.

21 What is light pollution?

It is excess — unneeded — artificial nighttime lighting that interferes with observing. The worst examples occur in large metropolitan areas. In the United States, 1.8 percent of energy generated goes to public outdoor lighting. Light pollution wastes $2.2 billion per year.

22 How many stars are visible from a dark site?

Most people could spot approximately 5,000 stars between the end of evening twilight and the beginning of morning twilight. Those with exceptional eyesight might boost the count to 8,000.

23 What is a Messier object?

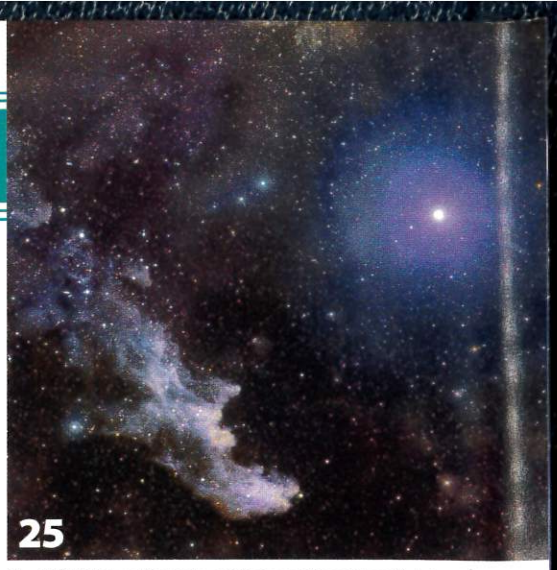
It is one of 109 deep-sky objects (star cluster, nebula, or galaxy) cataloged by French comet-hunter Charles Messier, who compiled the list so other observers would not mistake these objects for comets. For observers, Messier's list contains some of the sky's true wonders.

24 What percentage of stars are double or multiple?

Approximately 60 percent.

25 What makes the gas in a nebula glow?

Nebulae can glow by emitting or reflecting light. Atoms of gases like hydrogen can absorb energy from nearby stars and re-emit it as light of various colors. If the star is too far away to energize the atoms, the nebula can still reflect its light. As it does so, however, it also scatters the light, creating a characteristic blue color.



The Witch Head Nebula reflects and scatters light from the nearby star Rigel. ROGELIO BERNAL ANDREO

26 What is a planetary nebula?

It is a phase at the end of the life of every Sun-like star during which the outer atmosphere of the star expands into space. The core of the original star emits enough radiation to keep the nebula glowing for 10,000 years, on average.

27 What objects form from a star's death?

A Sun-like star will shed its outer layers as a planetary nebula. Its core will contract and become a white dwarf. It still contains most of the star's mass but will be only as big as Earth. More-massive stars will explode, producing supernova remnants rushing out into space. The cores of such stars will become either neutron stars (dense suns only a few miles across) or black holes.

28 What is a galaxy?

Each of these building blocks of our universe contains massive collections of stars, gas, dust, and associated unseen matter bound by gravity.

29 How many stars does the Milky Way contain?

Astronomers think between 250 billion and 400 billion stars populate our galaxy and that its total mass is somewhat less than 1 trillion Suns.

30 What's the universe made of?

Current estimates by cosmologists divide the universe into: dark energy, 68 percent; dark matter, 27 percent; free hydrogen and helium, 4 percent; stars, 0.5 percent; neutrinos and everything else, 0.5 percent.

Be an observer in 10 steps

Astronomy remains a vibrant science because something's always making news. In essence, the sky is calling. But how do you start observing the sky? What do you need to know?

1 Learn sky basics

Earth rotates once a day, so sky objects rise in the east and set in the west. It orbits the Sun once each year, making different constellations appear in each season.

The sky is a celestial sphere. It has a north pole, an equator, a south pole, and two sky coordinates: Right ascension is like longitude, and declination mimics latitude.

The Moon first becomes visible as a thin crescent low in the western evening sky. Each night thereafter, it appears to grow and move eastward until Full Moon, after which its lit part shrinks to invisibility.

2 Dive into the subject

Check out *Astronomy* magazine. It features a combination of science and hobby stories. "The Sky this Month" is an up-to-date guide to the current sky. And more is out there. Your public library and bookshops offer many observing guides.

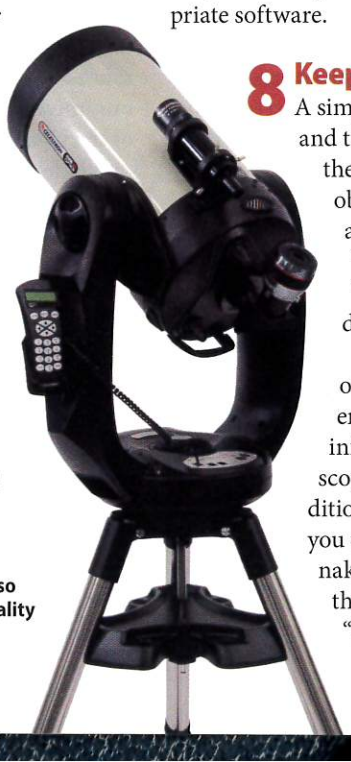
3 Try before you buy

Don't purchase a telescope without first viewing through it. One way to test-drive a scope is to attend an observing session or a star party hosted by an astronomy club. Take your time, ask lots of questions, and you'll soon enjoy a lifetime of viewing pleasure through your very own scope.

4 Pick your site carefully

If you'll be content with bright stuff, pretty much any location will do. To see faint, diffuse objects like nebulae and galaxies, however, you'll need a dark site.

Some things to consider are how light-polluted the observing location is, the driving distance, how portable your telescope is, safety (do you get cellphone service?), and weather factors, including how generally clear the sky is and how steady the air above you is.



You can spend a lot on a telescope, so make sure you're getting a high-quality product. Try it out first. CELESTRON

5 Double your observing time with the Sun

The Sun beckons beginning observers because it's big, bright, and full of features that change daily. Put safety first by using a filter, and even a small scope will deliver high-quality views.

Be sure to get a filter that fits correctly over the front end of your telescope. A good solar filter will not transmit harmful ultraviolet or infrared radiation. It also will drop the Sun's brightness to a viewable level.

6 Comfort is everything

Comfort means a lot more than staying warm in the winter. So, sit. When you are comfortable at the eyepiece, you'll see a great deal more. Many amateurs use adjustable chairs sold specifically for observing.

7 Photography: rewarding but time-consuming

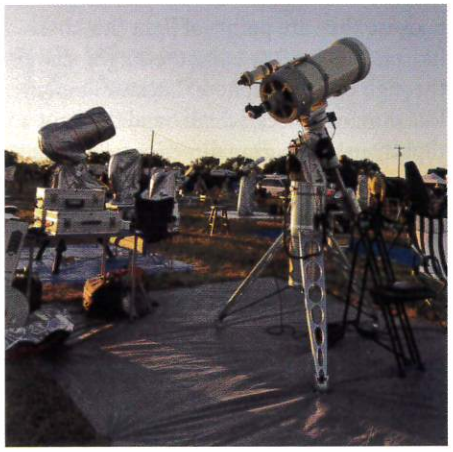
Here's the good news: You can take pictures of sky objects. Here's the other side: It takes practice, and there is a learning curve. Producing a high-quality picture involves two stages. First you acquire the data, and then you process it with appropriate software.

8 Keep a log

A simple log contains the date and time of your observation, the name or names of the objects you looked at, and a brief description, like, "Saw spiral arms!" or "Really blue, but no details visible."

Once you get the hang of it, more detailed log entries might contain information about the telescope, eyepiece(s), sky conditions, and the faintest star you could see with your naked eye. Observers call that quantity the sky's "limiting magnitude."

You don't need a telescope when you begin looking at sky objects. That said, you may soon want one because most of our fascinating universe lies beyond what our eyes can detect. NEIL KOPICKI



Interact with others and try out new telescopes and accessories by attending a star party. PHIL JONES

9 Get social

Visit a planetarium. Attend a star party. Observe with other amateur astronomers. Get on the Internet and chat in one of Astronomy.com's forums.

Without question, the best step you can take is to join a local astronomy club. This will place you with a group of like-minded individuals who can answer your questions.

10 Observe everything!

You may hear, "I'm a lunar observer," or "I only observe galaxies." Really? Are these observers saying they'd pass up watching a total solar eclipse, a bright comet, or a rich meteor shower?

The Moon has hundreds of targets on its ever-changing face, and even a small instrument will show most of them. The planets spend lots of time in the early evening sky. A trip now and then to a dark site may yield dozens of galaxies. While you take them all in, you'll surely marvel at the magnificent universe above and the richness of the hobby you have chosen.

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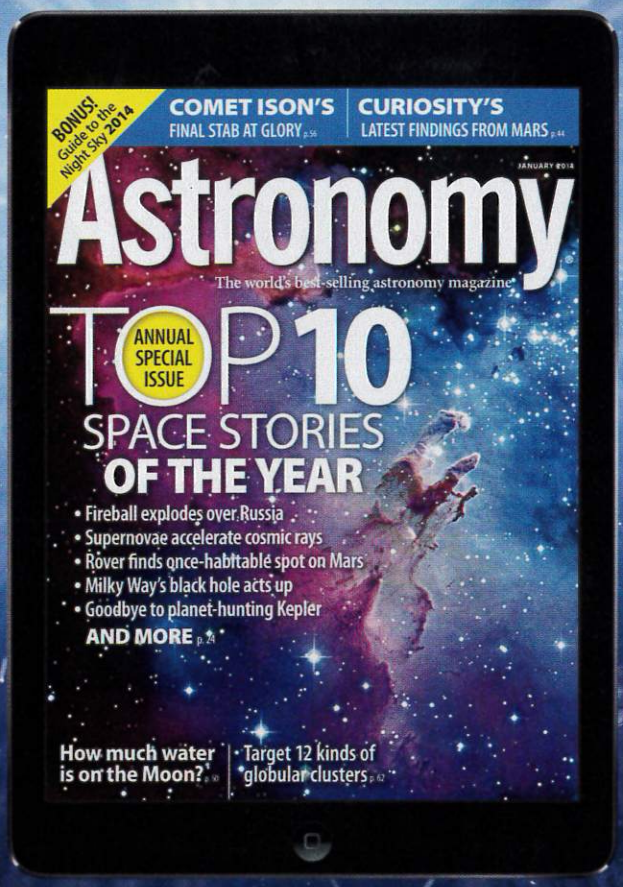

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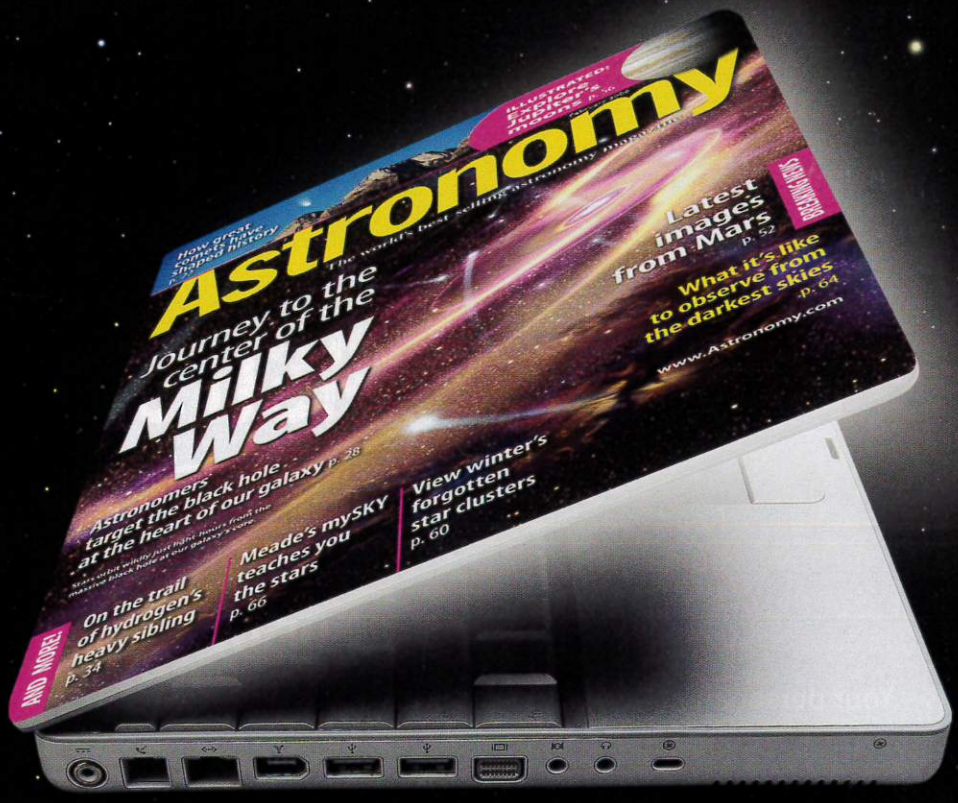

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