

The background of the cover is a collage of various celestial bodies. At the top left is a fiery orange and red planet. To its right is a grey, cratered moon. Further right is a large, detailed view of the Moon's surface. Below these are a green and blue planet, a white cratered moon, and a brown, textured moon. A dark, irregularly shaped asteroid is positioned in the center. The bottom half of the cover features a large orange planet on the left, a grey cratered moon in the center, a blue and green planet, and another grey cratered moon on the right. A dark brown, cratered moon is at the bottom center, and a reddish-brown planet is at the bottom right.

StarDate™

JANUARY/FEBRUARY 2022

\$6

MOONS GALORE

SKY ALMANAC

2022

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On the Cover

The planets of the solar system feature a dazzling array of moons, with frigid seas, underground oceans, huge volcanoes, and many other features.

This Page

A gibbous Moon over the Alaska Range in Denali National Park and Preserve.

Coming Up in March/April

Our next issue is all about cosmic jewels, from odd and beautiful galaxies to gemstones from the stars.

MOONS GALORE

On January 7, 1610, Galileo Galilei expanded the solar system. He saw three small “stars” aligning near the giant planet Jupiter. He followed them over the next few nights and saw that they and one other pinpoint of light stayed close to Jupiter but changed positions from night to night. Galileo quickly realized that these weren’t stars; instead, they were satellites of Jupiter—“moons” that move with the planet as our own moon moves with Earth.

Before long, astronomers were discovering moons all across the solar system, and they continue to find new ones today. They’ve found more than 200 moons orbiting the planets, including some with oceans below their icy crusts, one where dark geysers shoot into the sky, another with hundreds of active volcanoes, and one that’s surrounded by an atmosphere denser than Earth’s. Hundreds more moons orbit asteroids.

These satellite worlds formed along with their host planets, were captured by them, or were born from the rubble following collisions between their planets and other bodies. Some of the moons are doomed to crash or be pulverized in orbit, while a few will escape the grip of their planets and fly off into space.

Astronomers are extending the search for moons to planets in other star systems. So far, all they have are hints of such moons, but they know the moons must be there.

These small but numerous bodies add to the variety of the solar system (and other planetary systems), presenting a long list of questions for scientists to answer while giving the rest of us hundreds of intriguing and beautiful objects to enjoy from afar.

Text by Damond Benningfield

OVERVIEW

Four of the five naked-eye planets line up in the western evening sky at nightfall as the month begins, but two of them quickly drop from view. Only Saturn and Jupiter will be around by January's end. In the meantime, bold, beautiful Orion takes center stage in the early evening sky, with Sirius, the night sky's leading light, not far away.

HIGHLIGHTS

1 Four planets line up in the southwest shortly after sunset. Venus, the Evening Star, is just above the horizon. Mercury is close to its upper left, Saturn is farther to the upper left of Mercury, and Jupiter, the second-brightest member of the lineup, is farther to the upper left of Saturn. Venus and Mercury set by around the time the sky gets fully dark.

3 The Quadrantid meteor shower is at its best.

4 Earth is closest to the Sun today for the entire year, at a distance of 91.4 million miles (147.1 million km).

FEATURED EVENTS

4 Saturn stands close to the right of the Moon at nightfall.

5 Jupiter is close to the upper right of the Moon at nightfall.

6 The bright array in the early evening sky is, from top left, the crescent Moon, Jupiter, Saturn, and Mercury.

13 Aldebaran, the bright orange heart of the scorpion, stands to the lower right of the Moon at nightfall.

19/20 Regulus, the heart of the lion, is to the lower right/upper right of the Moon, respectively, as they climb into view by 8:30 or 9 p.m..

24 Spica, the leading light of Virgo, is to the lower right of the Moon as they climb into good view, after midnight this morning.

26 Zubenelgenubi, the southern claw of the scorpion, stands to the upper right of the Moon at first light.

27/28 Antares is the bright orange star near the Moon at first light. It represents the heart of Scorpius, the scorpion.

JANUARY

Su	M	T	W	Th	F	Sa
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16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

FEATURED EVENT



Planetary Stepping Stones

The worlds of the solar system will stage a grand display for the start of the new year. As January begins, four of the five planets that are easily visible to the unaided eye stairstep up the southwestern evening sky. One of them soon vanishes from view. The other three, however, are briefly joined by the crescent Moon, which races past them on the nights of January 3-6.

On New Year's Day, the lineup is anchored by Venus, the brilliant Evening Star, just above the horizon. It's quite low, so any buildings, trees, or other obstructions will block it from view. Mercury, the Sun's closest planet, is close to the upper left of Venus. Saturn is higher to Mercury's upper left, with Jupiter, the second-brightest planet, much higher.

Venus drops from view in a hurry, though, and will pass between Earth and the Sun on January 8, moving from evening to morning sky as it does so.

The Moon joins the lineup on January 3, forming a wedge with Mercury and Venus. It's the barest of crescents then, so most of its visible hemisphere will be illuminated by earthshine, which is sunlight reflecting off our own planet. All three worlds will set before twilight ends.

The next day, the Moon pays a call on Saturn, the Sun's second-largest planet. The day after that it perches close below Jupiter, the largest planet. And on January 6 it moves well to the upper left of Jupiter, forming the top point of the array of worlds. Venus will have vanished by then, leaving only three planets.

Mercury and Saturn will drop from view by the end of January, leaving Jupiter as the only planet in the evening twilight.

JANUARY

A Busy Year for the Moon

The Moon is getting busier. Several missions to our satellite world are scheduled for launch in 2022 (see page 15). Most of them are designed to help prepare the way for astronauts and advanced robots later in the decade.

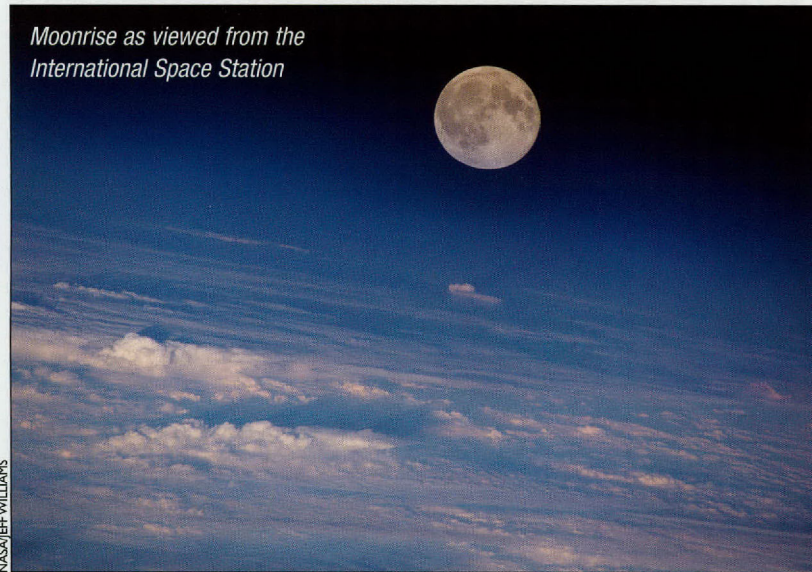
This year marks the 50th anniversary of the end of Apollo, which landed six missions on the lunar surface. Astronauts collected more than 840 pounds (340 kg) of rocks and dirt, which scientists around the world still examine. (Over the past two years, in fact, they've opened samples that had never been studied before, in part to develop techniques for storing and examining future samples.)

Combined with other observations, the samples revealed that the Moon probably formed when a planet rammed into the newborn Earth, spewing material into space. Much of that debris formed a ring around Earth that gave birth to one or more moons, which eventually coalesced

into a single survivor.

Scientists bounced laser beams off reflectors left on the Moon by the astronauts and by Soviet rovers. The observations showed that the Moon probably has a dense metallic core enveloped by a liquid outer core. They also revealed that the Moon is moving away from Earth at about 1.5 inches (3.8 cm) per year.

Robotic missions have discovered water ice mixed in with the dirt across the lunar surface, with heavy concentrations at the bottoms of permanently shadowed craters near the poles. As a result, many of the new robotic missions are targeting the south pole, where there appears to be the most ice. Studying the deposits could reveal details about the Moon's evolution. In addition, the ice could provide water, oxygen, and rocket propellants for future explorers. The lure of such resources could make the Moon even busier in the decades ahead.



Moonrise as viewed from the International Space Station

NASA/JEFF WILLIAMS

KEY DATES

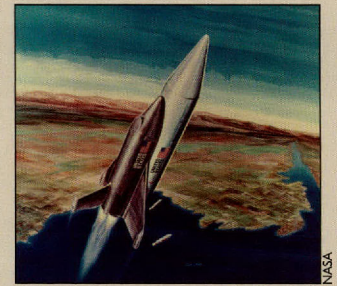
Date TBD

India is scheduled to launch Aditya-L1, its first Sun-watching mission. Its seven instruments will study the solar wind, the corona (the Sun's extended outer atmosphere), interactions between Sun and Earth, and other phenomena.

THIS MONTH IN HISTORY

January 5

President Richard Nixon approved the space shuttle program 50 years ago. Although it was billed as a cheap, flexible way to reach space, with up to one launch per week, it turned out to be expensive and persnickety. It took almost a decade to develop, NASA never launched more than nine missions in a year, and the shuttle totaled just 135 flights. Two of the five shuttles were destroyed, killing 14 crew members. The program ended in 2011.



NASA

An early concept shows a shuttle heading for space.

January 17

Elisabeth Hevelius, an early female astronomer, was born 375 years ago in Danzig, Poland. At age 16, she married 52-year-old Johannes Hevelius, one of the world's leading astronomers, in part because it allowed her to pursue her interest in astronomy. She observed the sky with him and, after his death, published a sky catalog they had compiled together.



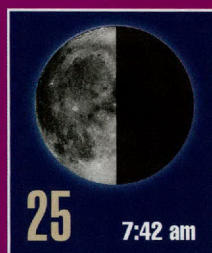
ANDREAS STECH/WIKIPEDIA

Hevelius watches the sky.

January 19

Johann Elert Bode was born 275 years ago, in Germany. A long-time director of Berlin Observatory, Bode is best known for his work on a formula, the Titius-Bode law, which found a pattern in the distances of the planets from the Sun. The concept gained favor after the discovery of Uranus (a name proposed by Bode) near the predicted position of a seventh planet. It broke down, however, with the eighth planet, Neptune, so the concept faded away.

Moon phases are Central Time.



The full Moon of January is known as the Old Moon, Moon After Yule, or Wolf Moon.

PERIGEE
January 1, 30

APOGEE
January 14

OVERVIEW

The stars of winter reign through the long February nights. Orion is in the south at nightfall, with Sirius, the brightest star in the night sky, twinkling fiercely to its lower left. Venus reigns as the Morning Star, and sticks close to much fainter Mars throughout the month. Mercury briefly joins them in the dawn sky at mid-month.

HIGHLIGHTS

- 2** Brilliant Jupiter, the solar system's largest planet, stands to the upper right of the Moon in the evening twilight.
- 9** Aldebaran, the eye of the bull, is below the Moon at nightfall.
- 12** Venus is at its brightest for its current Morning Star appearance, far outshining any other star or planet in the night sky.
- 13** Pollux, the brighter of the twin stars of Gemini, is close to the upper left of the Moon at nightfall. Castor, the other twin, is farther along the same line.
- 15** Mercury is at its best for its current morning appearance. It looks like a modestly bright star low in the southeast at first light, well to the lower left of brilliant Venus.
- 15-16** Regulus perches below the Moon as they rise in early evening on the 15th, and to the upper right of the Moon the following night.
- 19-20** Spica, the brightest star of Virgo, is below/to the upper right of the Moon, respectively, as they rise in late evening.
- 22** The Moon will stand just a whisker from Zubenelgenubi, one of the brighter stars of Libra, in the early morning hours.
- 24** Antares, the heart of the scorpion, is to the right of the Moon at dawn.

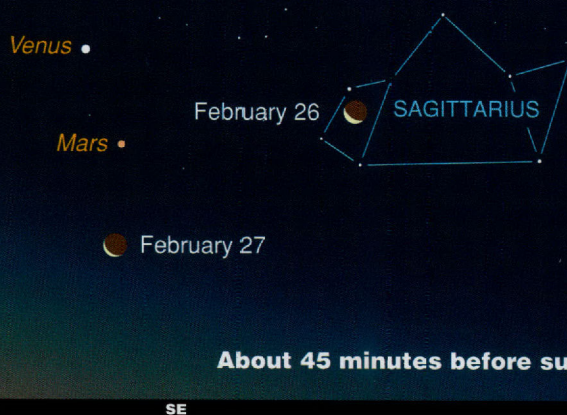
FEATURED EVENT

- 26** Venus and Mars stand to the left of the Moon at first light. Venus is the Morning Star, with much fainter Mars close below it.
- 27** Mars lines up above the Moon at first light, with Venus higher along the same line.

FEBRUARY

Su	M	T	W	Th	F	Sa
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27	28					

FEATURED EVENT



Quirky Neighbors at Dawn

Venus and Mars flank Earth like a pair of quirky neighbors. Venus is hot, bright, and mysterious. Mars is cold, bright, and mysterious. And this month, they stand close together in the dawn sky.

Venus is the Sun's second-closest planet and Earth's closest planetary neighbor, passing as little as 27 million miles (43 million km) away. Its surface is hellish, with temperatures of about 865 degrees Fahrenheit (450 C) across the entire planet and an atmospheric pressure more than 90 times Earth's surface pressure.

The atmosphere is topped by clouds made of sulfuric acid. They reflect most of the sunlight that strikes them, so the planet always shines brilliantly. Below the clouds, though, the sky is murky, with lighting comparable to twilight here on Earth.

It's also twilighty on Mars, but for a different reason: its distance from the Sun. Mars is the fourth planet from the Sun, at about twice the average distance of Venus, so it receives only about one-quarter as much sunlight.

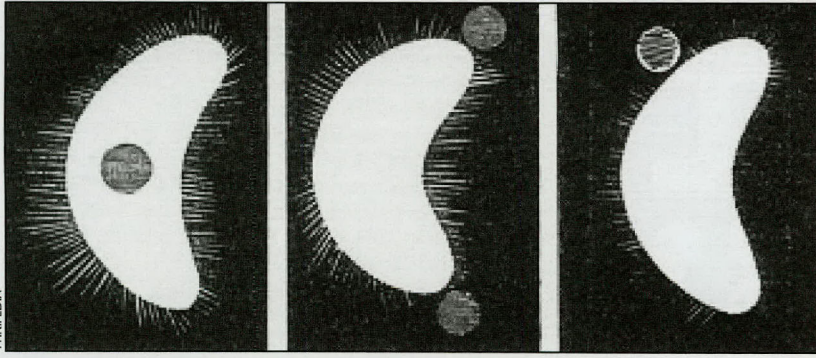
Mars's atmosphere is less than one percent as dense as Earth's, so it retains little solar heat, keeping temperatures far below zero most of the time.

Despite decades of close study, both planets retain a great deal of mystery.

Because Venus is shrouded in clouds, it's difficult to see its surface, so scientists are still trying to understand its history. And some scientists have suggested that microscopic organisms could live in the clouds. Mars has been mapped in great detail, but there are confusing indications about microscopic life below the surface.

Look for these neighbors in the southeast at first light. Fainter Mars huddles close by, with the two worlds skimming as little as five degrees from each other at the end of the month—half the width of your fist at arm's length. Mercury, the Sun's closest planet, will swoop into view to their lower left for much of the month.

FEBRUARY



Observations of a possible Venus moon by Francesco Fontana, 1646

False Moons

Venus and Mercury are the only planets in the solar system *sans* moons. In Mercury's case, it's not surprising. The planet is small, so its gravitational pull is weak, and it's close to the Sun, which would have blown away materials for making a moon, as Mercury was born.

Venus is more of a puzzle, though. It is only a little less massive than Earth and it's farther from the Sun than Mercury is, so you might expect it to host a satellite world, yet none has been found.

That's not for lack of trying, though. Astronomers have scanned the space around Venus since the invention of the telescope, and more than 40 have reported success.

In 1672, for example, Giovanni Cassini, one of the greatest astronomers of his time, described a moon that was about one-quarter Venus's diameter. Several other astronomers confirmed the discovery, although others saw nothing.

The sightings continued for decades. In 1761, for example, when Venus crossed the face of the Sun, a couple of observers said they saw a moon. Others, who looked just as

diligently, saw nothing. Astronomers looked again during a crossing in 1769. They saw nothing.

An 1887 study concluded that most of the sightings of the previous two centuries actually were stars that had appeared especially close to Venus.

Astronomers have looked for moons several times since then, including a close scan in 2009. It, too, saw nothing.

A study in 2006, however, suggested that Venus could have had a moon early in its history. A large body could have collided with the planet, blasting out debris that coalesced to form a moon (the same mechanism thought to have given birth to Earth's moon). Later, a second impact caused Venus to spin in the opposite direction. That caused the moon to crash into Venus, leaving it moonless.

KEY DATES

February 2

CALENDAR EVENT

Legend says that if a groundhog sees its shadow when it pokes its head out of its burrow on February 2, winter will last another six weeks; if not, expect an early spring. In ancient Britain, February 2 was known as Candlemas, and it represented the end of winter and the beginning of spring.

February 24

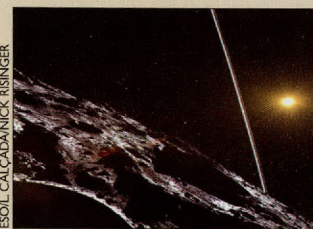
Today is the autumnal equinox in the northern hemisphere of Mars. It marks the beginning of autumn north of the equator and spring south of the equator.

THIS MONTH IN HISTORY

February 12

A meteor blazed across the skies of Russia 75 years ago today. It was brighter than the Sun and produced a deafening sound. It exploded in the atmosphere, with some of its fragments falling in the Sikhote-Alin Mountains. An estimated 23 tons of material survived the impact.

February 15

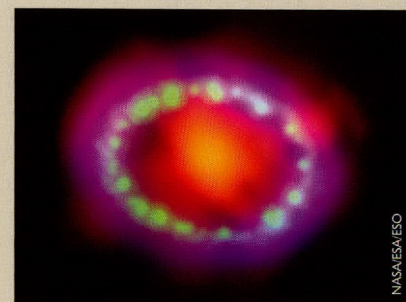


An artist's concept shows rings arching above Chariklo

Astronomer James V. Scotti discovered Chariklo, a giant asteroid that orbits between Saturn and Uranus, 25 years ago. It's the largest known object in that region of the solar system, with an estimated diameter of roughly 156 miles (252 km). In 2014, astronomers discovered a pair of rings, making Chariklo the smallest known object in the solar system with rings.

February 23

Supernova 1987a, the closest exploding star to Earth in centuries, was discovered 35 years ago. The supernova was roughly 168,000 light-years away, in the Large Magellanic Cloud, a satellite galaxy of the Milky Way. Astronomers monitor it regularly, watching the debris expand and evolve. They eventually discovered the star's dead core, a neutron star.



Observations from three telescopes show the supernova 20 years after it exploded.

Moon phases are Central Time.



The full Moon of February is known as the Snow Moon, Wolf Moon, or Hunger Moon.

APOGEE
February 10

PERIGEE
February 26

OVERVIEW

A trio of planets congregates in the southeastern sky at dawn, getting closer together as March progresses. The brightest of the three is Venus, the dazzling Morning Star. Mars is to its lower right as the month begins, with Saturn far to their lower left. The three worlds converge late in the month, forming a prominent triangle. The crescent Moon sweeps past them on the morning of the 28th, adding to this beautiful March highlight.

HIGHLIGHTS

- 5** Jupiter is in conjunction today, passing behind the Sun as seen from Earth. It will return to view, in the morning sky, next month.
- 8** The thick crescent Moon slips between Aldebaran and the Pleiades this evening. Bright orange Aldebaran is the eye of Taurus. The dipper-shaped Pleiades star cluster, to the right of the Moon, is the bull's twinkly shoulder.
- 9** Aldebaran lags below the Moon this evening. El Nath, the tip of one of the bull's horns, is about the same distance above the Moon.
- 15** Regulus, the bright heart of Leo, crouches to the lower right of the Moon at nightfall.
- 19** Spica, the leading light of Virgo, is the bright star to the right or lower right of the Moon late this evening.
- 20** Venus stands farthest from the Sun for its current Morning Star appearance. It is well up in the southeast at dawn, with Mars and Saturn close by.

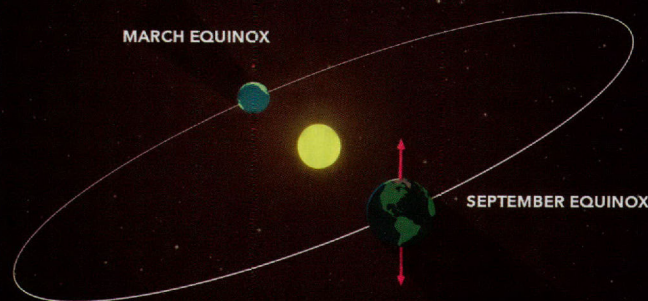
FEATURED EVENT

- 20** Today is the vernal equinox, marking the beginning of spring in the northern hemisphere. It occurs at 10:33 a.m. CDT.
- 23** Antares, the bright orange star at the heart of the scorpion, is quite close below the Moon at first light.
- 28** The Moon, Venus, Saturn, and Mars form a beautiful group at first light. Venus is the brilliant Morning Star, with Saturn close below it. Mars is about the same distance to the right of Venus.

MARCH

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FEATURED EVENT



Springing a New Season

The Sun crosses the celestial equator heading from south to north on March 20. Known as the vernal equinox, this moment marks the beginning of spring in the northern hemisphere.

To be more precise, it marks the start of *astronomical* spring, which is only one way to mark the seasons.

The modern western calendar evolved from the calendar of ancient Rome. Originally, the year began around the time of the March equinox. In 46 B.C., Julius Caesar instituted the basic version of the calendar that's in use today, with 12 months, a start date of January 1, and a leap day every fourth year. (The calendar has been tweaked since then to revise the number of leap days.)

Even so, there were no standard beginning and ending dates for the seasons. Some regions used the equinoxes and solstices, while others used these dates as seasonal mid-points. In Britain, for example, the June solstice was Mid-Summer's Day. In this system, the seasons changed roughly half-way between the solstices and equinoxes, on the cross-quarter days. These were (and, in some cases, still are) commemorated with such events as Groundhog Day and what is now Halloween.

Over time, though, many cultures adopted the solstice-and-equinox system of delineating the seasons. These events are based on the precise position of the Sun in the sky, so they are easy to predict long in advance. The official timekeeping organization in the United States, the U.S. Naval Observatory, reckons the seasons along these astronomical events, so spring officially begins at the moment of the vernal equinox.

There are many other ways to designate the seasons, of course. In the meteorological calendar, autumn begins on September 1, when the weather begins to cool for most of the country. The school year begins in August or September (COVID has complicated things), with "winter" starting after the Christmas break and summer beginning around the first of June. But the astronomical seasons begin and end with the solstices and equinoxes.

MARCH

Tiny Moons, Big Mystery

For such tiny objects, the moons of Mars sure cause a lot of trouble. Planetary scientists have tried to puzzle out their origins since the moons were discovered, but so far there's no agreement on any scenario. Instead, the list of possibilities just keeps getting longer.

Phobos and Deimos were discovered in 1877. Phobos (which means fear) is 15 miles (24 km) across and orbits 3,700 miles (5,900 km) from Mars. Deimos ("dread") is just nine miles (14 km) across and about 9,000 miles (14,400 km) farther.

For decades, the leading idea said the moons were asteroids that were captured by Mars when they passed close to the planet. Modern calculations, however, suggest that such a scenario is unlikely, so scientists have developed other ideas.

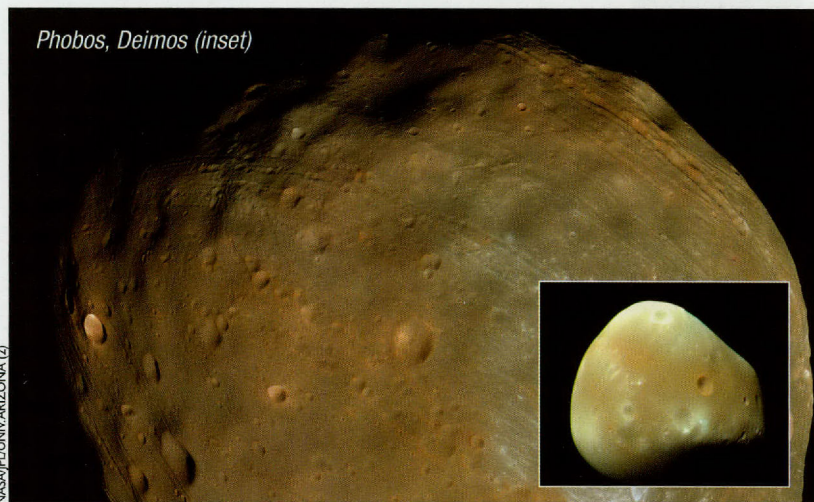
One says that, like Earth's moon, Phobos and Deimos formed when a good-sized body slammed into Mars, blasting out debris that formed a ring around the planet. Some of the material coalesced to form the moons. A variation of that idea says

the impact created a larger moon, and its gravity helped shape Phobos and Deimos from debris farther from Mars. (The bigger moon later crashed into Mars.)

Another study suggests the moons originally were part of a larger body that was split apart by an impact with a third body, such as a passing asteroid or comet. And yet another says that Phobos could have disintegrated and reformed several times over the eons, growing smaller with each cycle.

Landing on one of the moons and determining its chemistry could help settle the issue. Three attempts by the Soviet Union and Russia have failed, but Japan is scheduled to launch a Mars moons mission in 2024.

While their origins remain mysterious, their fates are not. Phobos is spiraling toward Mars, and within 50 million years or so should be pulverized by the planet's gravity, forming a ring. Deimos, on the other hand, is retreating, and eventually should escape the Red Planet.



NASA/JPL/UNIVERSITY OF ARIZONA (2)

KEY DATES

March 14

Today is Pi Day (selected for the date's numerical designation: 3rd month, 14th day, or day 3.14, the first three digits of pi). It honors the mathematical constant that expresses the ratio between the circumference and diameter of a circle.

www.piday.org

SKY WATCH

Viewing the Planets

VENUS

The brilliant planet starts 2022 as the Evening Star, but vanishes from view within days as it crosses between Earth and Sun. It will return, as the Morning Star, by the middle of January, and will stay in the morning sky until September. It then vanishes behind the Sun, and it won't reemerge—back in the evening sky—until December.

JUPITER

The largest planet in the solar system, and usually the brightest object in the night sky after the Moon and Venus, shines at its best in early autumn, when it is brightest and is in the sky all night. It spends most of the year in the constellation Pisces, the fishes.

MARS

Orange Mars spends the first half of the year low in the pre-dawn sky before climbing higher later on. It's at its best in early December, when it aligns opposite the Sun and outshines everything else except the Moon, Venus, and Jupiter.

MERCURY

The Sun's closest planet is in the evening sky in early January, late April into early May (its best evening apparition), August, and December. It appears in the morning sky in late February through mid-March, June, and October (best morning showing).

SATURN

The ringed planet shines brightest this year in August, as it moves through the constellation Capricornus, the sea-goat.

URANUS

The seventh planet is at its brightest in early November, when it barely reaches naked-eye visibility. Most skywatchers will need optical aid to spot it, though.

Ranked in order of maximum brightness when not too near the Sun

Moon phases are Central Time.



The full Moon of March is known as the Sap Moon, Worm Moon, or Lenten Moon.

APOGEE
March 10

PERIGEE
March 23

OVERVIEW

The favorite constellations of the season spring into view in the early evening sky. Leo is well up in the east at nightfall, with Regulus, the bright star that marks his heart, leading the way. Virgo is low in the sky at nightfall but climbs to prominence quickly, highlighted by Spica. Four of the five planets visible to the unaided eye are in good view in the early morning, including the two brightest, Venus and Jupiter, which stage a spectacular encounter.

HIGHLIGHTS

- 4-5** Saturn and Mars are almost atop each other at dawn these mornings. The planets are to the right or upper right of Venus, the Morning Star.
- 5** Aldebaran is the bright star near the Moon at nightfall.
- 6** El Nath, "the butting one," stands close to the upper right of the Moon at nightfall. The star forms the tip of one of the horns of Taurus, the bull, but also belongs to the outline of adjoining Auriga the charioteer.
- 9** Pollux and Castor, the twins of Gemini, line up to the right of the Moon at nightfall, in that order.
- 11-12** Regulus, the brightest star of Leo, is below/to the upper right of the Moon on these evenings, respectively.
- 15-16** Spica takes its turn near the Moon on these nights.
- 19** Antares is to the lower left of the Moon at first light.
- 22** The Lyrid meteor shower should be at its best early this morning.
- 24-27** The Moon swings past the planets Saturn, Mars, and the close pairing of Venus and Jupiter, in that order, in the early morning sky.
- 27-28** Neptune will move past Venus, the Morning Star, in the early morning sky. You need good binoculars or a telescope to see the giant planet, which looks like a faint star.

FEATURED EVENT

- 29-May 2** Venus and Jupiter stage a conjunction in the dawn sky.
- 30** A partial solar eclipse will be visible from the far-southern hemisphere.

APRIL

Su	M	T	W	Th	F	Sa
					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

APRIL

FEATURED EVENT



About 45 minutes before sunrise

EAST

A Protective Big Brother

Venus and Jupiter—the brightest pinpoints of light in the night sky, stage a spectacular conjunction low in the dawn sky in late April and early May. At their closest, on April 30 and May 1, they'll be just half a degree apart, which is less than the width of a pencil held at arm's length. Venus, the Morning Star, is the brighter of the two.

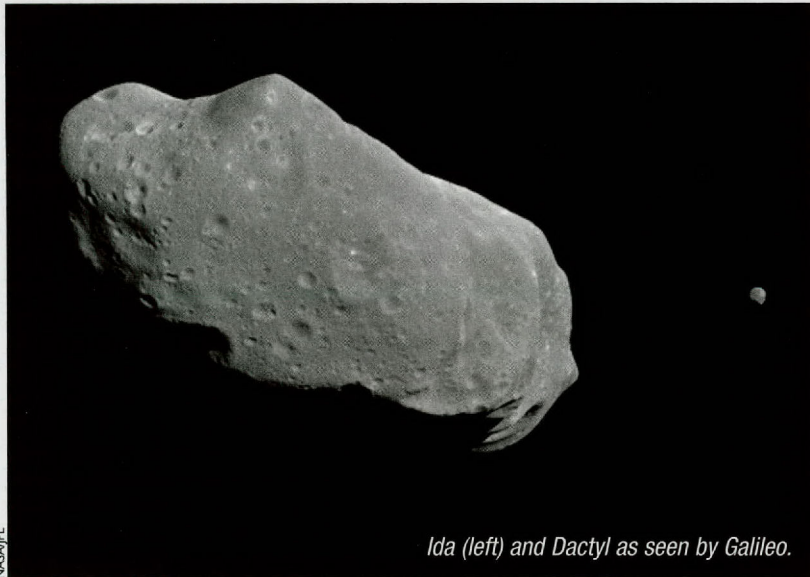
Venus and Jupiter are sibling worlds, which means they were born at about the same time, from the same cloud of gas and dust that surrounded the newborn Sun. And Jupiter has been a cuddling big brother, protecting Venus and the other inner planets, including Earth. It's even possible that Venus owes its existence to Jupiter.

Venus is roughly the same size as Earth and is the second planet out from the Sun. Jupiter, the fifth planet, is more than 11 times Earth's diameter and more than 300 times its mass.

Because of Jupiter's great heft, the planet's gravity exerts a strong influence on the other objects in the solar system. When the solar system was young, Jupiter's gravity hurled many leftover planetary building blocks, known as planetesimals, out of the solar system. That reduced the number of collisions between planetesimals and Venus and the other inner planets.

Models say Jupiter briefly migrated much closer to the Sun than it is today. That could have pushed an initial set of inner planets into the Sun. As Jupiter moved outward again, new planets—perhaps including Venus and Earth—formed from the debris. (Another idea says the close-in Jupiter altered Venus's orbit, creating the hellish conditions seen on the planet's surface today.)

Venus begins the month close to Saturn and Mars, with Jupiter lost in the twilight. Later, however, Venus will drop toward the Sun while Jupiter climbs away from it, so the distance between the planets will shrink in a hurry. The Moon huddles close to them on April 27.



Ida (left) and Dactyl as seen by Galileo.

Moonlets Everywhere

Most of the moons in the solar system are chips off the old block—tiny fragments of rocky asteroids or the icy bodies found beyond the orbit of Neptune, the Sun’s most-distant planet. Astronomers have discovered moons orbiting more than 400 asteroids, including a few systems with more than one moon. The moons range from a few hundred feet to a few miles in diameter. (There are also quite a few double asteroids, in which the members of the system are roughly the same size and mass.)

The first asteroid moon was discovered in 1993, when the Galileo spacecraft flew past Ida, a member of the asteroid belt. Galileo’s images revealed a moon tagging along with the asteroid. Named Dactyl, the moon is about a mile (1.6 km) in diameter, compared to 35 miles long (56 km) for Ida.

The most likely way for an as-

teroid to get a moon is through a collision with another asteroid. If the impact is at the right speed and angle, it can chip off a chunk of rock and send it into orbit. If the impact is too strong, though, the debris sails away into space, leaving the parent asteroid behind. And if it’s especially strong, it pulverizes the asteroid, leaving behind only a cloud of dust.

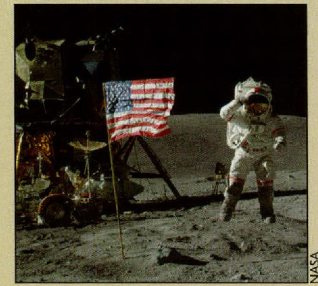
Another spacecraft is scheduled to visit an asteroid-moon system this fall. Double Asteroid Redirection Test (DART) will ram into Dimorphos, a moon of Didymos. Astronomers will measure how the impact alters the moon’s orbit around Didymos. The results could help scientists develop techniques for deflecting any future asteroid on a collision course with Earth. DART’s observations also will add to our knowledge of asteroid moons in general, improving models of how they form and evolve.

KEY DATES

THIS MONTH IN HISTORY

April 20

The penultimate Apollo mission landed on the Moon 50 years ago, in 1972. Astronauts John Young and Charles Duke spent three days in a region known as the Plains of Descartes. They logged 20 hours outside their lunar module, Orion, during three moonwalks, and used a rover to cover 16.6 miles (26.7 km). They then rejoined



John Young jumps as he salutes the American flag.

Ken Mattingly aboard the command module, Casper, for the return to Earth. Mattingly conducted a spacewalk during the trip home to retrieve film from cameras he operated during his time alone in lunar orbit.

April 22

The discovery of gold at Sutter’s Mill in the mountains of California triggered a 19th-century gold rush. Another treasure appeared there 10 years ago today, when a brilliant meteor exploded in the early morning sky, raining debris across the countryside. About 80 fragments have been discovered, with the largest weighing just seven ounces. They contain material left over from the birth of the solar system.

METEOR SHOWERS

SHOWER	PEAK*	MOON
Quadrantids	Night of January 2	New, so won’t interfere
Lyrids	Night of April 21	In view during peak hours
Eta Aquarids	Night of May 5	Sets before peak hours
Perseids	Nights of August 11/12	Full Moon, in view all night
Draconids	Night of October 8	Full Moon, in view all night
Orionids	Nights of October 20/21	Crescent, rises during peak
Leonids	Nights of November 16/17	In view during peak hours
Geminids	Night of December 13	In view during peak hours

* Actual times may vary

Moon phases are Central Time.



1
1:24 am



9
1:48 am



16
1:55 pm



23
6:56 am



30
3:28 pm

The full Moon of April is known as the Egg Moon or Grass Moon.

APOGEE April 7 | **PERIGEE** April 19

OVERVIEW

The great planetary conjunctions just keep rolling along. Venus and Jupiter begin this month as they ended the previous one, appearing to almost touch each other in the dawn sky. Jupiter stages a similarly close encounter with Mars late in the month. With summer approaching, however, sunrise comes early, so you'll need to awaken in the wee hours of the morning to catch the action.

HIGHLIGHTS

- 2** Aldebaran stands to the left of the Moon, and the planet Mercury to the lower right, as night falls. Mercury is slightly brighter than Aldebaran.
- 6** Pollux and Castor, the twins of Gemini, line up to the right of the Moon, with Pollux especially close to it.
- 9** Regulus stands below the Moon at nightfall.
- 13** Spica is the star to the right of the Moon this evening.

FEATURED EVENT

- 15** The Moon will pass through Earth's shadow tonight, creating a total lunar eclipse.
- 16** Antares, the heart of the scorpion, is quite close to the right of the Moon as they climb into good view by 10:30 or 11 p.m.
- 17-18** Mars passes less than one degree from the much fainter planet Neptune these mornings. Through binoculars or a telescope, Neptune will look like a small star to the left of/above Mars on these mornings, respectively.
- 22** Saturn perches above the Moon at first light.
- 24-25** Jupiter and Mars line up to the left of the Moon at first light on the 24th, and to the upper right of the Moon on the 25th. Jupiter is by far the brighter planet.
- 26-27** Venus, the Morning Star, shines to the lower left/upper right of the Moon, respectively, during the dawn twilight these days.
- 27-31** Jupiter and Mars stage an especially close encounter in the early morning sky. They are closest to each other on the 29th, separated by less than one degree.

MAY

Su	M	T	W	Th	F	Sa
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				

MAY

FEATURED EVENT

Crossing Paths Redux

The Moon slips through Earth's shadow on the night of May 15, creating a total lunar eclipse. It comes exactly one year after another total eclipse—not one calendar year, but one lunar year, which is about 11 days shorter.

A lunar eclipse occurs when the Moon passes through Earth's shadow, temporarily darkening at least part of the lunar disk.

Eclipses don't happen every month, however, because the Moon's orbit around Earth is tilted relative to Earth's orbit around the Sun. Most months the Moon passes above or below the shadow, so there's no eclipse. An eclipse takes place only when the full Moon is crossing the plane of Earth's orbit, placing our satellite world in the shadow.

It's a total eclipse if the Moon completely enters the dark inner shadow, the umbra. If the umbra covers only part of the lunar disk, it's a partial eclipse.

Eclipses can take place at intervals of one "lunation" (the period from one full Moon to the next, roughly 29.5 days), five lunations, or, most commonly, six lunations, known as a semester. Two semesters make a lunar year, which is 354.4 days long. Lunar eclipses can repeat one semester apart in a series of eight eclipses. The eclipses in such a cycle aren't all visible from the same part of Earth, but there is overlap from one eclipse to the next.

This month's eclipse comes one semester after the last one, on November 19, 2021, and a full lunar year after another. There will be another total eclipse one semester from now, on November 8, and one more eclipse in a lunar year, on May 5, 2023. That eclipse will be penumbral, with the Moon barely shaded by Earth's faint outer shadow.

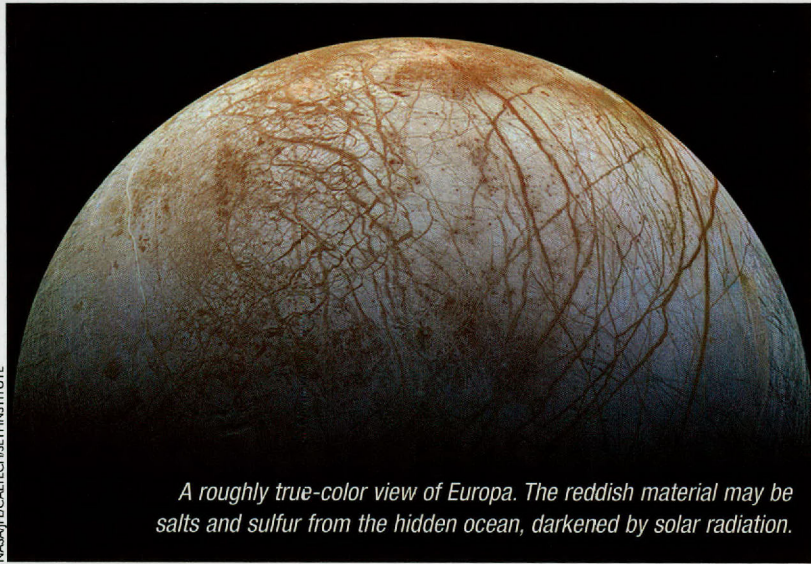
ECLIPSE OF MAY 15/16, 2022

- 9:27 p.m.** Partial eclipse begins as Moon first touches the umbra
- 10:29 p.m.** Moon fully immersed in the umbra; total eclipse begins
- 11:54 p.m.** Moon begins to leave the umbra; total eclipse ends
- 12:55 a.m.** Moon leave the umbra; partial eclipse ends

All times are Central Daylight Time

VIEWING FROM THE UNITED STATES

- The eastern and southeastern half of the country will see the entire eclipse.
- From the western U.S., the eclipse will be in progress as the Moon rises.
- Most of Alaska will be shut out; the Moon will be leaving the umbra as it rises in Hawaii.



A roughly true-color view of Europa. The reddish material may be salts and sulfur from the hidden ocean, darkened by solar radiation.

Plunging into a Deep Ocean

To find life in the solar system, scientists probably need to go deep. In the case of Jupiter's moon Europa, for example, life might exist miles below the surface, in a global ocean of liquid water.

Europa is widely considered one of the most likely homes for life in the solar system. Cracks, grooves, ridges, and other features on its surface suggest that its icy crust, which is about 10-15 miles (15-25 km) thick, floats atop a layer of liquid water. Mathematical models suggest the water forms an ocean 40-100 miles (60-160 km) deep that covers the entire moon. So even though Europa is smaller than the Moon, it probably holds more liquid water than all of Earth's oceans combined.

Tidal forces like those that create the ocean tides on Earth ripple through Europa, stretching and squeezing it and generating heat that keeps the ocean from freezing. The heat also could produce volca-

nic vents at the bottom of the ocean, like those found in Earth's oceans. The vents could belch jets of hot, mineral-rich water into the ocean. If so, that would give the ocean all the basic ingredients for life: liquid water, heat, and a rich brew of the right chemical compounds.

We should learn more about life on Europa over the next decade or so. The European Space Agency plans to launch a mission to study the big moon in August (see page 19), with a NASA mission following in 2024. NASA also is studying the possibility of sending a lander in the 2030s. It would drill into the crust, perhaps revealing frozen water from the ocean that hasn't been zapped by radiation or impacts by small space rocks. And scientists are pondering the possibility of sending a small submarine to drill through the ice and swim through the ocean, providing a direct view of this promising extraterrestrial habitat.

KEY DATES

May 1

Today is May Day, an event that has been celebrated with bonfires for centuries. The date is a cross-quarter day, which falls roughly half way between a solstice and an equinox. In many cultures, these dates marked the beginning of the seasons, so May 1 was the first day of summer.

THIS MONTH IN HISTORY

May 31

Charles Greeley Abbot, an astrophysicist who studied the Sun and eventually led the Smithsonian Institution, was born 150 years ago. He established a small observatory that looked for changes in the Sun's energy output, and invented several solar-powered devices, including a solar cooker.



Abbot measures solar energy, ca. 1915

SKY WATCH

2022 ECLIPSES

DATE	TYPE	VIEW FROM U.S.
April 30	Solar: Partial	None
May 15/16	Lunar: Total	Most of the country
October 25	Solar: Partial	None
November 8	Lunar: Total	Most of the country

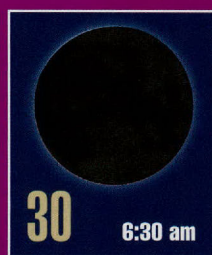
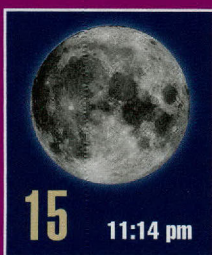
TOTAL LUNAR ECLIPSE The Moon is completely covered by Earth's dark inner shadow, turning the lunar surface dark.

PARTIAL LUNAR ECLIPSE Earth's shadow covers only part of the lunar disk, so it looks as though something has taken a bite out of it.

TOTAL SOLAR ECLIPSE The Moon passes between Earth and Sun, completely covering the Sun's disk.

PARTIAL SOLAR ECLIPSE The alignment isn't quite right for a total eclipse, so the Moon covers only part of the Sun's disk.

Moon phases are Central Time.



The full Moon of May is known as the Milk Moon, Flower Moon, or Corn Moon.

APOGEE
May 5

PERIGEE
May 17

OVERVIEW

The planetary action remains concentrated in the dawn and pre-dawn sky, with Venus, Jupiter, and Mars visible all month, and Mercury for part of the month. Uranus is there as well, but you need binoculars to spot it. Scorpius climbs into great evening view during June, with its severed claws—now part of Libra—preceding it.

HIGHLIGHTS

- 5** The bright star close to the lower left of the Moon at nightfall is Regulus.
- 9** Spica is close below or to the lower left of the Moon as night falls.
- 11** Zubenelgenubi, which represented one of the claws of Scorpius, is close to the upper right of the Moon at nightfall.
- 12-13** Antares is to the lower left/upper right of the Moon at nightfall on these evenings, respectively.

FEATURED EVENT

- 13** The Moon is full tonight. It is the Short-Night Moon.
- 16** Mercury is farthest from the Sun for its current morning appearance. Even so, the little planet is quite low in the east-southeast during twilight, well to the lower left of Venus. Binoculars will enhance the view.
- 18/19** Saturn stands above the Moon at first light on the 18th, and is to the right or upper right of the Moon on the 19th.
- 21** Brilliant Jupiter perches close to the upper left of the Moon at first light, with Mars farther to the left.
- 21** Summer arrives in the northern hemisphere at 4:14 a.m. CDT, which is the moment of the June solstice.
- 22** Mars is close to the left of the Moon at first light, with Jupiter farther to the upper right.
- 24** Mercury and Venus line up to the lower left of the Moon, with Mars and Jupiter to the upper right. Uranus is closer to the lower left of the Moon in the late dawn twilight and is an easy target for binoculars.
- 25-26** Venus, the Morning Star, is to the lower left/to the right of the Moon on these mornings, respectively, with Mercury to their lower left.
- 27** Mercury is close to the right of the Moon at first light, with brilliant Venus well to their upper right.

JUNE

Su	M	T	W	Th	F	Sa
			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		

FEATURED EVENT

A Shortness of Moonlight

The Moon makes itself scarce on the night of June 13. Since it will be “full” on the morning of the 14th, it will rise around sunset and remain in view all night. But because the night is short, so is the time for moonwatching. In fact, among other names, June’s full Moon is known as the Short Moon or Short-Night Moon.

The length of time the full Moon is in view varies by season and by latitude. At the equator, it’s always in view for about 12 hours. As you move away from the equator, though, there’s a bigger difference based on the time of year.

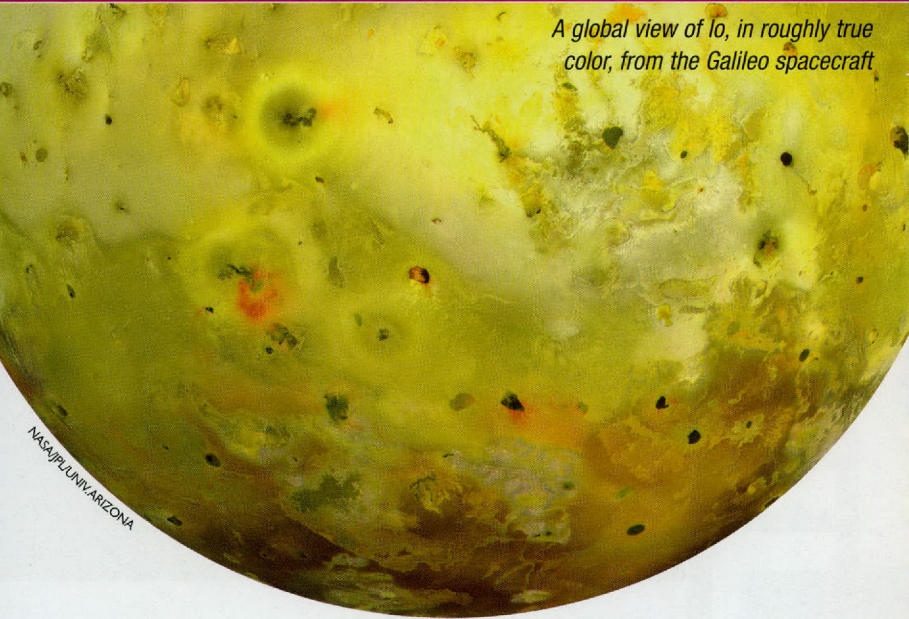
That’s because Earth is tilted on its axis. At this time of year—near the start of northern summer—the north pole dips sunward. So during the day, the Sun sails high overhead for northern latitudes and stays in view for a long time—up to about 16 hours as seen from the Lower 48 States, and up to 20 hours or more from parts of Alaska.

But since it lines up exactly opposite the Sun in the sky, the full Moon always does just the opposite of what the Sun does. So if the Sun is high in the sky and in view for a long time, then the Moon is low in the sky and in view for a much briefer time. Denver, for example, will see only about 10 hours of moonlight on the 13th, while Moon-deprived Anchorage will be graced with the Moon’s presence for only about seven hours. The following night will be about the same.

So wherever you are, enjoy the last evening of spring and the beautiful moonlight—but do it in a hurry.

The full Moon rises beyond an abandoned mission at Pecos National Historical Park, New Mexico.





A global view of Io, in roughly true color, from the Galileo spacecraft

NASA/JPL/UNIV. ARIZONA

Hot-Headed Moon

Jupiter's moon Io is like the rope in a mammoth tug of war. It's being pulled by Jupiter on one end and the moons Europa, Ganymede, and Callisto on the other. Jupiter wins, so the same hemisphere of Io always faces the giant planet, just as the same hemisphere of the Moon always faces Earth. Yet the other big moons exert a strong enough pull to have a big influence on Io—they make it the most volcanically active body in the solar system.

Io is about the same size as the Moon, and the same distance from Jupiter as the Moon is from Earth. That's where the comparisons end, though. More than 400 active volcanoes dot the surface of Io. Some of them blast material up to 300 miles (500 km) high, while others produce lava lakes hundreds of miles long. The lava is much hotter than anything seen

on modern-day Earth.

The volcanoes are powered by the tug of war. As the other big moons sweep past Io, they try to turn it away from Jupiter. That generates friction within the moon that melts rock not far below the surface. The magma forces its way to the surface through thin spots and cracks.

Some of the volcanoes are so powerful that they blow material into orbit around Jupiter, forming a doughnut-like structure around the planet. Charged particles in that ring create radiation belts far deadlier than Earth's. They also help create auroras and even lightning on Jupiter.

Motions within the molten rock below the surface cause the crust to move. In some places, it squeezes together to form mountains. The tallest are higher than Mount Everest, adding to Io's tortured surface.

KEY DATES

THIS MONTH IN HISTORY

June 5

John Bolton was born 100 years ago in England. He worked on radar during World War II, then moved to Australia, where he applied his knowledge of radio technology to astronomy. Bolton found that several radio sources were far outside the galaxy, while others were the remnants of dead stars.

EXPLORATIONS

Back to the Moon

NASA and other space agencies plan to dispatch several robotic spacecraft to the Moon. These are the earliest times each is likely to launch.

MISSION	COUNTRY	LAUNCH
IM-1	USA	February-March
Scheduled to land in Ocean of Storms, carrying several instruments to measure the environment around the spacecraft		
Peregrine 1	USA	February-March
Scheduled to land in Lacus Mortis, a small volcanic plain, carrying 11 NASA instruments and other payloads		
Artemis I	USA	Spring
Test flight of Orion spacecraft, which will carry astronauts to the Moon; booster will deploy small orbiters to look for water ice		
Chandrayaan-3	India	Third Quarter
Successor to the failed Chandrayaan-2 mission; will consist of a lander and a small rover		
Luna 25	Russia	July
Continuation of Soviet missions of the 1960s and '70s, will land at Bugoslavsky Crater near the south pole and analyze the lunar surface		
KPLO	South Korea	August
Korea Pathfinder Lunar Orbiter will look for lunar resources, such as water, uranium, and silicon, and map future landing sites		
IM-2	USA	November
Scheduled to land near the south pole; will drill into the surface to hunt for water and carry a small "hopper" to enter dark craters		
SLIM	Japan	Unknown
A small lander will demonstrate the technology to conduct precision landings in scientifically interesting locations		

Moon phases are Central Time.



The full Moon of June is known as the Flower Moon, Strawberry Moon, Rose Moon, or Honey Moon.

APOGEE
June 1, 29

PERIGEE
June 14

OVERVIEW

Scorpius and Sagittarius highlight the July sky, scooting low across the south during the night. Bright orange Antares highlights the scorpion's hook-shaped body, with teapot-shaped Sagittarius to its left. Under dark skies, the Milky Way rises from the teapot's spout like steam. Meanwhile, the Big Dipper stands high in the north and northwest during the evening, looking especially dipper-like, with its handle to the upper left and bowl at the lower right. And the brilliant Summer Triangle is in good view in the east by mid-evening and climbs high overhead in the wee hours of the morning.

HIGHLIGHTS

- 2-3** Regulus stands to the left/lower right of the Moon, respectively.
- 4** Earth is at aphelion, its farthest point from the Sun for the year.
- 6-7** Spica is to the lower left/lower right of the Moon at nightfall.

FEATURED EVENT

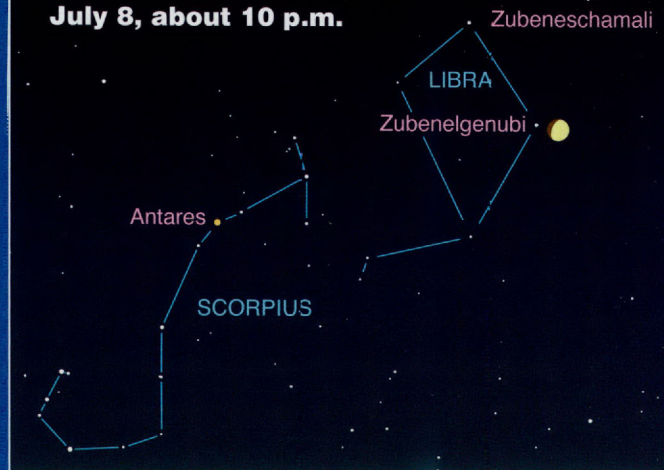
- 8** The Moon takes aim at Zubenelgenubi, one of the ancient claws of nearby Scorpius.
- 10** Antares, the orange heart of the scorpion, is close to the Moon tonight.
- 14-15** The planet Saturn stands to the left/upper right of the Moon as they climb into good view a couple of hours after sunset on these evenings.
- 18-19** Brilliant Jupiter is close to the Moon at dawn.
- 21-22** Mars takes its turn as the Moon's companion, posing quite close to the lower left of the Moon at first light on the 21st and farther to the upper right on the 22nd.
- 23-24** Aldebaran is below/to the right of the Moon at first light on these mornings, respectively.
- 26-27** Venus, the Morning Star, stands close to the lower right of the Moon at first light on the 26th, and farther to the upper right of the Moon on the 27th. The Moon will be quite low in the sky as morning twilight brightens on the 27th.

JULY

Su	M	T	W	Th	F	Sa
					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						

FEATURED EVENT

July 8, about 10 p.m.



Striking a Balance

Like Bruce Wayne and Clark Kent, the stars Zubenelgenubi and Zubeneshamali have dual identities. Officially, they are the brightest stars of Libra, the balance scales. Yet their odd names refer to much older identities, when they were part of the adjoining constellation Scorpius, the scorpion. The names identify them, respectively, as the southern and northern claws.

The Moon will pass quite close to the claws on the night of July 8. Zubenelgenubi will stand just to the left of the Moon at nightfall, with the Moon nudging closer to it later on. From the West Coast, in fact, they'll be almost touching by the time they set, in the wee hours of the morning, and they will pass even closer as seen from Hawaii—less than the width of the Moon itself. Zubeneshamali will perch to their upper left by about the width of your fist held at arm's length.

In ancient Babylon, where many of the constellations we recognize today were first drawn, Libra didn't exist. Instead, Scorpius covered a much larger portion of the sky, incorporating Zubenelgenubi and Zubeneshamali.

Later cultures severed the claws, though, because of the Sun's migration across the sky. A few thousand years ago, the Sun passed in front of the claws at the time of the September equinox, a time when day and night are of roughly equal length—a time of "balance" in the heavens. That led to the creation of Libra, a constellation that represents balance.

Zubenelgenubi may be a quadruple star system. Binoculars reveal two stars. They're separated by about 140 times the distance between the Sun and Pluto. They share the same motion through space, suggesting they are gravitationally bound to each other, but the great gap between them makes that hard to confirm. Scientific instruments reveal that each of the stars has a close companion, giving the scorpion's severed southern claw a total of at least four stars.

Seas on the Surface, Oceans Below

In some ways, the surface of Titan, the largest moon of Saturn (and second-largest moon in the solar system, after Jupiter's Ganymede) looks a lot like Earth. Mountains, volcanoes, and big fields of sand dunes are sprinkled across it. Rivers and streams flow into lakes and seas, one of which contains more liquid than all the Great Lakes combined. Clouds sometimes produce torrential rainfall.

There's one big difference, though. The average temperature on Titan is roughly 290 degrees below zero Fahrenheit (-180 C), so the ground is made of water ice that's as hard as granite, and the liquid that falls from the sky and fills the lakes and seas consists of frozen methane and ethane.

Despite the extreme cold, Titan is still considered a possible (if unlikely) abode for life. Its atmosphere, which is denser than Earth's, is

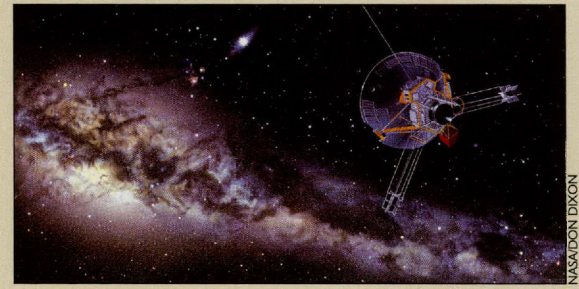
made of nitrogen with smatterings of organic molecules. The organic compounds form an orange smog that hides the surface from view (spacecraft use radar and wavelengths of light that are invisible to the eye to peek through the smog). It's possible that the organic chemistry could support life forms that are quite different from those on Earth.

In addition, there's evidence that a large ocean of salty, ammonia-rich liquid water forms a global ocean below the icy crust. The ocean could contain more water than all of Earth's oceans combined. It could provide conditions that are comfortable for organisms similar to those on Earth.

NASA is developing a drone, Dragonfly, to measure Titan's chemistry as it flies through the thick atmosphere. Launch is scheduled for 2027, with arrival in 2034.

KEY DATES

THIS MONTH IN HISTORY



An artist's concept shows Pioneer 10 heading into interstellar space.

July 15

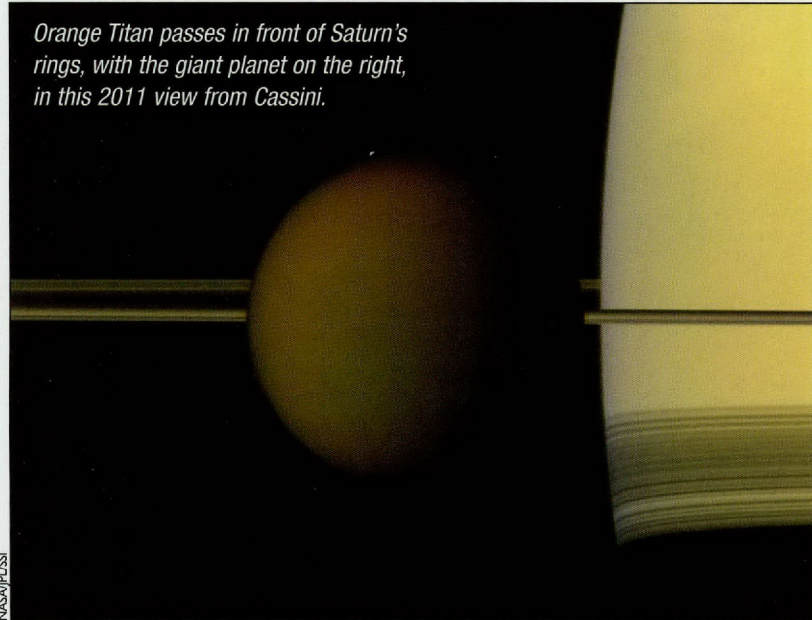
Pioneer 10 became the first spacecraft to enter the asteroid belt, which is between the orbits of Mars and Jupiter, 50 years ago. Defying the expectations of science fiction, it made the seven-month crossing unscathed. It recorded a jump in particles 0.1 to 1 millimeter in diameter, but otherwise was zapped by fewer bits of debris than expected. Pioneer 10 later became the first spacecraft to fly past Jupiter, and the first to exit the solar system.

July 22

Venera 8, the second successful Venus lander, touched down 50 years ago, in 1972. It recorded readings on the atmosphere as it parachuted the final 35 miles (60 km) to the surface, finding the air clear and dusky below about 20 miles (30 km). It confirmed that surface temperatures and pressures are extremely high. The landing module survived for 50 minutes in the harsh conditions.

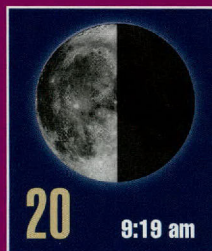
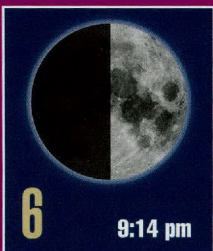


X marks the landing spot of Venera 8 in this image from the Magellan Venus orbiter.



Orange Titan passes in front of Saturn's rings, with the giant planet on the right, in this 2011 view from Cassini.

Moon phases are Central Time.



The full Moon of July is known as the Hay Moon, Thunder Moon, or Apollo Moon.

PERIGEE
July 13

APOGEE
July 26

OVERVIEW

Sagittarius and Scorpius dominate the southern sky on August evenings. Both of the ancient star patterns are easy to pick out, even under moderate light pollution. Some of the bright stars of Sagittarius, which leads the scorpion across the sky, form the outline of a teapot, while Scorpius forms an easily recognizable hook. Ophiuchus the serpent bearer wheels above them, flanked by the head and tail of the serpent.

HIGHLIGHTS

1 Mars passes close to the giant planet Uranus. They are high in the east-southeast at first light. Mars looks like a fairly bright orange star. Uranus is to the upper left of Mars on the 1st, by about the width of a finger at arm's length, and is an easy target for binoculars. They will remain close for several days.

3 Spica lines up just below the Moon at nightfall.

6-7 Orange Antares, the heart of the scorpion, is close to the left or lower left of the Moon at nightfall on the 6th, and farther to the right of the Moon on the 7th.

FEATURED EVENT

11 Saturn is close to the upper left of the Moon as they rise, shortly after nightfall. The giant planet will reach opposition on the 14th, putting on its best showing for the entire year.

12 The Perseid meteor shower should be at its best tonight, although the almost-full Moon will drown out all but the brightest meteors.

14 Brilliant Jupiter, the solar system's largest planet, hangs close to the upper left of the Moon as they climb into good view in late evening.

19 Mars is close below the Moon as they climb into view, after midnight, and stays close the rest of the night.

20 Aldebaran, in Taurus, is to the lower right of the Moon at first light, with Mars farther to the upper right of the Moon.

25 Venus, the Morning Star, stands below the Moon in the dawn twilight. It is quite low, however, so you need a clear horizon to see it.

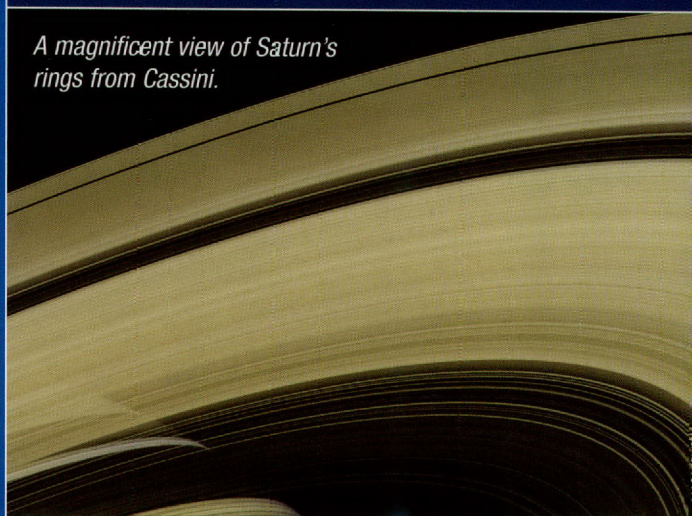
30 Spica is close to the lower left of the crescent Moon at nightfall, quite low in the sky.

AUGUST

Su	M	T	W	Th	F	Sa
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7	8	9	10	11	12	13
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FEATURED EVENT

A magnificent view of Saturn's rings from Cassini.



Zeroing in on Saturn's Rings

Through a telescope, the most impressive view in the solar system might be the rings of Saturn. The main rings span about three-quarters the distance from Earth to the Moon, with some faint outer rings roughly doubling that reach. The rings are no more than a few hundred feet thick, however, and probably a good bit thinner, so they almost disappear when viewed edge-on. Ring particles, which range from the size of dust grains to boulders, consist almost entirely of frozen water, with a small amount of rock and dust mixed in.

Thanks to the Cassini spacecraft, which orbited Saturn for a dozen years, planetary scientists are drawing closer to a consensus on the age and fate of the rings. Most recent studies say the rings are no more than 100 million years old (compared to some earlier estimates, which placed their age at up to 4.5 billion years—as old as Saturn itself). And material from the inner rings is “raining” into Saturn's upper atmosphere so quickly that, if they're not replenished, the rings should disappear in a few hundred million years.

Scientists still don't agree on how the rings formed. One idea says they were born when Saturn's gravity pulled apart a passing comet and the remains encircled the planet. Another says they formed from one or more collisions between small moons or between a moon and a comet, ripping the objects to bits and scattering ice and other debris around Saturn.

The rings are in especially good view this month because Saturn is at opposition on August 14. It lines up opposite the Sun in our sky, so it rises at sunset and is in view all night. It is closest for the year, too, so it shines brightest. It looks like a bright golden star on the western side of Capricornus.

The full Moon will slide past Saturn on August 11, making it easier to locate but overpowering the giant planet's fainter glow for a few nights.

AUGUST



Views from Cassini show the bright surface of Enceladus with Saturn's rings in the background, and plumes from the moon's south pole (inset).

NASA/PLISSI (2)

Sampling a Deep Ocean

One of Saturn's outermost rings, the faint E ring, is sustained by the planet's most intriguing moon, Enceladus. The Cassini spacecraft discovered that geysers of water and ice are erupting from cracks near the moon's south pole. Some of that material spreads out along the orbit of Enceladus, forming the wide but tenuous E ring.

Enceladus is only about 315 miles (500 km) in diameter. Its surface is coated by relatively fresh ice, so it's one of the most reflective bodies in the solar system—as white as untainted snow. Cassini's observations suggest that the surface is constantly repaved by ice from the geysers, keeping it pristine.

The geysers appear to erupt from

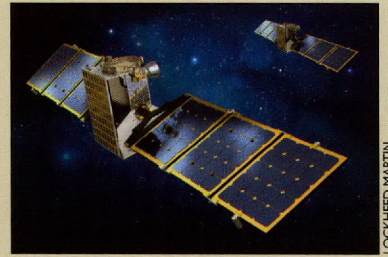
an ocean beneath Enceladus's icy surface. As Saturn's gravity pulls at the little moon, its interior is twisted and heated, warming some of the ice below the surface and forming the ocean. It appears to be several miles deep.

Cassini collected samples of the ocean water as it flew through the geyser plumes during several close passes. It found organic molecules and other interesting compounds in the plumes. That suggests that, like Jupiter's moon Europa, Enceladus could have all the ingredients for life: abundant water, the right chemistry, and a source of heat. As a result, Enceladus is considered one of the solar system's most promising places to look for life.

KEY DATES

August 1

NASA is scheduled to launch two asteroid explorers. Psyche will study a metallic asteroid of the same name in the asteroid belt. The asteroid Psyche, which is about 140 miles (226 km) in diameter, may be the leftover core of an early planet. The other mission, Janus, will dispatch two small satellites—each about the size of a piece of carry-on luggage—to study two binary asteroids in 2026.



LOCKHEED MARTIN

An illustration depicts the twin Janus craft en route to the asteroid belt.

August 26

Jupiter ICy moons Explorer (JUICE) is scheduled for launch. The European mission will study Jupiter and its large, icy moons, Europa, Ganymede, and Callisto. It will reach Jupiter in 2031, then enter orbit around Ganymede—the largest moon in the solar system—the following year, making it the first craft to orbit the moon of another planet. It will study the subsurface oceans of the three big moons and look for the chemistry of life at Europa.

THIS MONTH IN HISTORY

August 10

Earth dodged a cosmic bullet 50 years ago when a small asteroid skipped off the atmosphere above the western United States and Canada. It formed a brilliant fireball with a long tail. Studies have indicated the object was up to 45 feet (14 meters) wide. A more head-on collision could have caused extensive damage.

August 12



MCDONALD OBSERVATORY

Otto Struve

Otto Struve, the first director of McDonald Observatory, was born 125 years ago today in Russia. His father, grandfather, and great-grandfather were accomplished astronomers. He emigrated to the United States, where he joined the University of Chicago. He later became director of its Yerkes Observatory and helped broker an arrangement for Chicago to operate McDonald Observatory for the University of Texas.

Moon phases are Central Time.



The full Moon of August is known as the Grain Moon or Green Corn Moon.

PERIGEE
August 10

APOGEE
August 22

OVERVIEW

A new season opens up in the evening sky. Pegasus slides into view in the east shortly after night falls, marked by the Great Square, while the constellations of the “celestial sea”—Capricornus, Aquarius, Pisces, and others—flow across the south.

HIGHLIGHTS

- 1** Zubenelgenubi, the star that once represented the southern claw of Scorpius, stands close to the right of the Moon at nightfall.
- 2-3** Antares, the brightest star of the scorpion, stands to the left/lower right of the Moon at nightfall on these dates, respectively.
- 5** The Moon occults the star Tau Sagittarii, briefly blocking it from view. The star connects the bottom of the handle to the teapot of Sagittarius.
- 7-8** The bright planet Saturn perches to the upper left/upper right of the Moon, respectively, at nightfall.
- 10** The Moon is full today. As the full Moon closest to the autumnal equinox, it's the Harvest Moon.
- 10-11** Jupiter, the second-brightest point of light in the night sky, is to the left/upper right of the Moon, respectively, in early evening.
- 16** Neptune is at opposition. It is in view all night and is closest to Earth, so it shines brightest. You need a telescope to see it, however.
- 16-17** Mars and Aldebaran line up below/to the right of the Moon as they climb into good view, after midnight on these mornings. Both look bright orange, with Mars on the left. On the 17th, the star El Nath will be to the left of the Moon.
- 20** The Moon lines up with the twins of Gemini at first light.
- 22** Autumn arrives in the northern hemisphere at 8:04 p.m. CDT, the moment of the equinox. The Sun crosses the celestial equator, which is the projection of Earth's equator on the sky, from north to south.
- 23** Regulus is close to the right of the Moon at first light.

FEATURED EVENT

- 26** Jupiter is at opposition.
- 28** Zubenelgenubi is close above the Moon at nightfall.
- 30** Antares is quite close to the lower right of the Moon at nightfall.

SEPTEMBER

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SEPTEMBER

FEATURED EVENT

A Whole New View

Jupiter is like a whole new planet. Observations by the Juno spacecraft, which has been orbiting Jupiter since 2016, have led to discoveries about the planet's interior, its magnetic field, its atmosphere, and its giant storms, providing a dossier that's quite different from the one compiled pre-Juno.

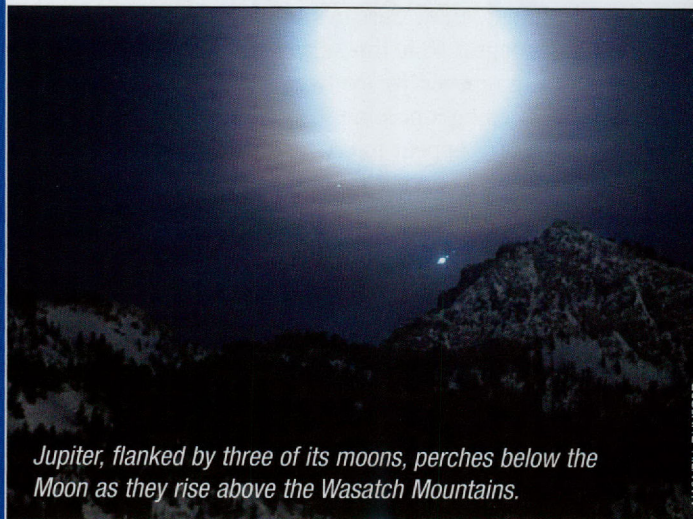
Before Juno, for example, planetary scientists hypothesized that Jupiter's core was a dense ball of rock and metal many times the mass of Earth. By measuring Jupiter's gravitational and magnetic fields, however, Juno determined that the core is spread out and mixed with lighter materials, like a slushball. The structure suggests that Jupiter was hit by another planet, perhaps 10 times the mass of Earth, early in its history, shattering its core and mixing it with the surrounding layers.

The craft also found that powerful jet streams in the atmosphere extend as far as 2,000 miles (3,200 km) below the cloud tops, causing fluctuations in Jupiter's gravitational field.

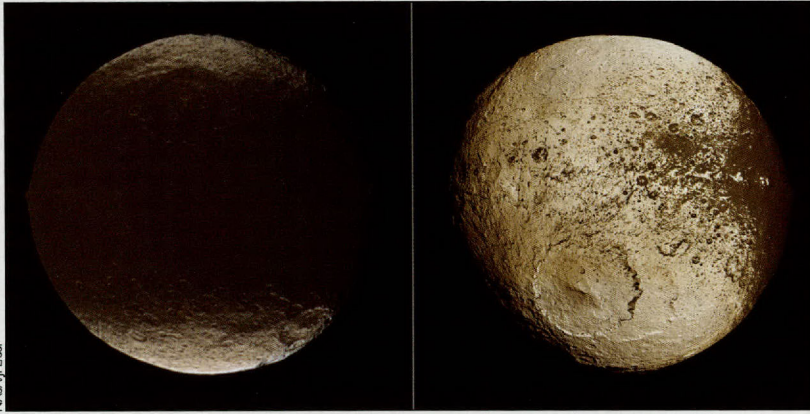
Juno also showed that the Great Red Spot, a storm wider than Earth, extends to depths of about 300 miles (500 km). And the craft discovered that clouds of ammonia and water produce lightning much higher in the atmosphere than any seen before, as well as giant hailstones—“mushballs” of ammonia and water that plunge miles into the thicker atmosphere below.

As 2021 ended, Juno continued to orbit Jupiter, perhaps making new discoveries that will continue to refresh our concepts of the solar system's largest planet.

Jupiter puts in its best showing of the year this month, as it reaches opposition on September 26—it lines up opposite the Sun. It rises due east around sunset and remains in view all night. It's closest to Earth for the year as well, so it's at its brightest. It outshines everything else in the night except the Moon and Venus.



Jupiter, flanked by three of its moons, perches below the Moon as they rise above the Wasatch Mountains.



Cassini images show the two-faced appearance of Iapetus. Its equatorial ridge is visible in both images.

Saturn's Yin-and-Yang Moon

One of the moons of Saturn is two-toned: One hemisphere is quite bright, while the other is almost as dark as coal. The difference may be caused in part by another of Saturn's moons.

Iapetus was discovered in 1671 by Giovanni Cassini. It's 914 miles (1,472 km) in diameter, which is less than half the size of Earth's only natural satellite, the Moon. It's about nine times farther from Saturn than the Moon is from Earth. It probably consists mainly of water ice mixed with a small amount of rock. A ridge around most of its equator makes it look like a walnut. One hypothesis says the ridge might have formed when material in an early ring around Iapetus fell onto its surface.

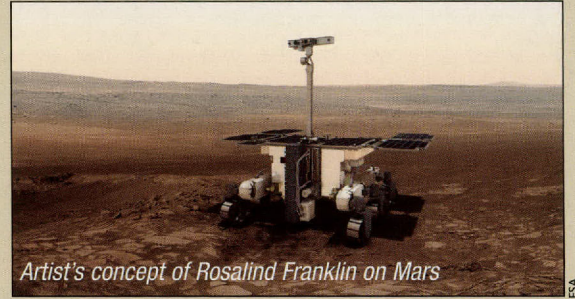
Cassini noticed something odd about his discovery: He could see Iapetus only when it was on one side of Saturn, not the other. He deduced that Iapetus always keeps the same hemisphere turned toward Saturn, just as the same hemisphere of the Moon always

faces Earth. Cassini also realized that the hemisphere of Iapetus that always faces forward must be bright, the other hemisphere dark.

The Cassini spacecraft (named for Giovanni), which orbited Saturn for more than a decade, provided a great look at that two-toned appearance. Its images showed that there's a sharp line between light and dark.

The leading hemisphere of Iapetus may get coated with dust that is blasted off the surface of Phoebe, another moon. The dust would trap sunlight during the day, warming the ice below it and causing some of the ice to vaporize. Some of it might then migrate to the trailing hemisphere when it's nighttime. Once there, it would freeze, making the dark side darker and the bright side brighter.

KEY DATES



Artist's concept of Rosalind Franklin on Mars

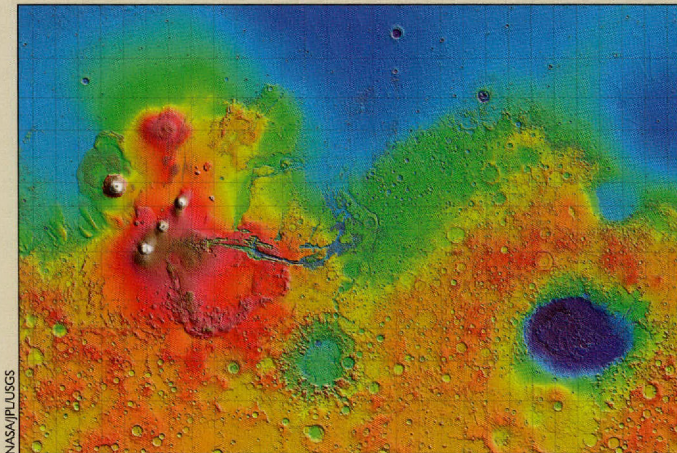
September 20

The launch window opens for the Rosalind Franklin Mars rover, a joint European and Russian project that was delayed from 2020. Landing is scheduled for June 10, 2023, in Oxia Planum, a plain that contains clays, which formed in a wet environment. The rover will drill into the Martian surface and extract samples for analysis in an on-board laboratory. Its primary goal is to search for evidence of past life on Mars. The rover's namesake played a key role in the discovery of DNA.

THIS MONTH IN HISTORY

September 11

Mars Global Surveyor entered orbit around Mars 25 years ago, beginning a mission that lasted more than 19 years, which is second only to Mars Odyssey. It mapped the entire planet (including elevation maps), studied the atmosphere, and served as a communications relay for several landers. It failed in November 2006, but is expected to remain in orbit for another quarter of a century.



An elevation map of Mars compiled from Global Surveyor observations; red is higher, blue is lower

Moon phases are Central Time.



The full Moon of September is the Fruit Moon or Green Corn Moon. This year it's also the Harvest Moon.

PERIGEE
September 7

APOGEE
September 19

OVERVIEW

Autumn's major constellations span the sky from east to south by the middle of the evening. The array includes Pegasus, Andromeda, Perseus, Cetus, and Auriga. Mars creeps into the late-evening sky early in the month and rises earlier by month's end. It looks like a bright orange star, and it grows brighter through the month.

HIGHLIGHTS

5 Saturn, the second-largest planet in the solar system, stands to the upper right of the Moon at nightfall.

7-8 Jupiter, the largest planet in the solar system, stands to the left/upper right of the Moon at nightfall on these dates, respectively.

8 Mercury, the smallest planet in the solar system, stands farthest from the Sun for its current morning appearance. It looks like a bright star, low in the east at dawn.

9 The Moon is full today. As the full Moon after the Harvest Moon, it's known as the Hunter's Moon.

FEATURED EVENT

11 The Moon occults the planet Uranus, covering it from view as seen from Alaska, most of Canada, and the western half of the Lower 48 States.

13 Aldebaran is to the lower right of the Moon as they climb into good view, in mid-evening.

14 Mars is close to the lower right of the Moon as they climb into good view, in late evening.

20 Regulus crouches to the lower right of the Moon at first light.

21 The Orionid meteor shower should be at its best late tonight. The Moon won't interfere with the show.

25 A partial solar eclipse will be visible across Africa, Europe, and parts of Asia, but not North America.

OCTOBER

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30	31					

FEATURED EVENT



Uranus (small blue-green dot) appears near a partially eclipsed Moon in 2014.

Making a Giant Disappear

If a seldom-seen planet disappears, does anyone notice? We'll find out on the night of October 11, when the Moon briefly slides in front of the giant planet Uranus, hiding it from view.

At four times Earth's diameter, Uranus is the third-largest planet in the solar system. But it's so far away—an average of about 1.8 billion miles (2.9 billion km)—that it's tough to see. At its peak, and under especially clear, dark skies, it's just bright enough to see with the unaided eye. Realistically, though, all but the most experienced skywatchers need binoculars to pick it out, so almost no one has ever seen it. In fact, it wasn't "discovered" until 1781—with the help of a telescope.

Uranus is an almost featureless blue-green orb. Its most intriguing feature is something you can't see: its angle—it's tipped over on its side. Planetary scientists have devised several possible explanations. It could have been hit by another planet when it was young, for example, or pummeled by several impacts over a longer period, or twisted around by an encircling disk of gas and dust as it was being born, among other possibilities. Whatever its cause, the tilt creates extreme seasons on Uranus, as the north and south poles take turns aiming directly at the Sun.

Uranus's vanishing act will be visible from much of the United States—anything west of a line from New Mexico to Wisconsin (including Alaska). The exact timing depends on the viewing location, but the earliest contact takes place at 11:31 p.m. CDT, and Uranus returns to view by 2:50 a.m. From the eastern part of the country, Uranus will appear just a whisker away from the Moon. As always, though, you'll need help to spot this seldom-seen giant.

OCTOBER

A Big Moon in Reverse

Neptune, the Sun's most remote major planet, was discovered in September 1846. Just 17 days later, British astronomer William Lassell discovered the planet's biggest moon, Triton. It's one of the most intriguing moons in the solar system. It has a thin atmosphere and volcanic activity, and geysers of dark ice squirt up to five miles (eight km) high, depositing material up to 100 miles (160 km) away.

Triton is a little smaller than our moon. It's the only major moon that orbits in the opposite direction from its planet's rotation. It might have been a Pluto-like dwarf planet that was captured by Neptune. Triton also is the coldest major body in the solar system—colder even than Pluto, which is farther from the Sun.

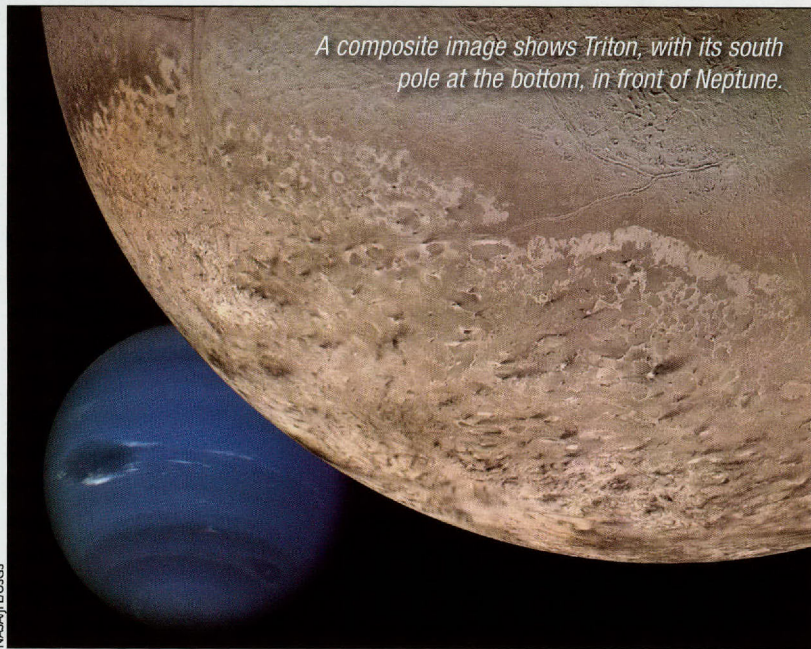
Our only close look at Triton came from Voyager 2, in 1989. Its pictures showed that Triton has a young sur-

face. Instead of ancient impact craters, it's covered by young volcanic plains. Much of the surface looks like the skin of a cantaloupe.

Voyager also showed that Triton has an atmosphere that's thick enough to support plumes from the geysers, which may form as sunlight warms ices below a layer of frozen nitrogen. The ices expand, then burst through the nitrogen layer and climb high into the sky.

Neptune's relentless gravitational pull could heat frozen water below Triton's surface, creating an ocean of liquid water like the ones suspected on some of the big moons of Jupiter and Saturn.

Simulations show that Triton is doomed. It is spiraling closer to Neptune, and within a few billion years it should either ram into Neptune or be ripped apart by the planet's gravity, creating a massive ring system.



A composite image shows Triton, with its south pole at the bottom, in front of Neptune.

NASA/JPL/USGS

KEY DATES

October 1

This is International Observe the Moon Night, which was established to commemorate achievements in lunar exploration.

moon.nasa.gov/observe-the-moon-night/about/overview

THIS MONTH IN HISTORY

October 14

Chuck Yeager became the first pilot to exceed the speed of sound in controlled, level flight 75 years ago. He flew the Bell XB-1 rocket plane, named Glamorous Glennis for his wife, from Muroc Field, California.



JACK RIDLEY/USAF

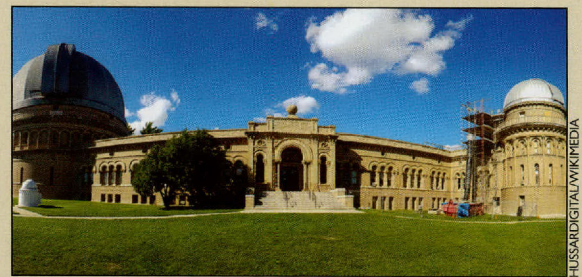
Yeager poses in the XB-1 cockpit after his flight.

October 15

A meteorite struck a cow near Trujillo, Venezuela, 50 years ago today, killing the animal instantly.

October 21

Yerkes Observatory, in Williams Bay, Wisconsin, was dedicated in 1897—125 years ago today. The observatory was established by the University of Chicago. Its original telescope was a 40-inch refractor, which is still the largest telescope of its type in the world. Yerkes was a key center for the development of astrophysics—studying the physics of stars, galaxies, and other objects. Chicago transferred the observatory to a non-profit group in 2020, and it was scheduled to reopen for public and educational programs this year.



HUSSARDIGITAL/WIKIMEDIA

A 2016 view of Yerkes Observatory

Moon phases are Central Time.



2

7:14 pm



9

3:55 pm



17

12:15 pm



25

5:49 am

The full Moon of October is known as the Dying Grass Moon or the Hunter's Moon.

PERIGEE
October 4, 29

APOGEE
October 17

OVERVIEW

The second total lunar eclipse of the year for most of the United States highlights the month, although there's plenty to see throughout November. Mars brightens during the month and moves closer to another bright orange pinpoint, Aldebaran, the eye of Taurus. In the second half of November, another denizen of the bull, the sparkly Pleiades star cluster, reaches its highest point in the sky about midnight.

HIGHLIGHTS

- 1** Saturn stands directly above the Moon at nightfall. It looks like a bright golden star.
- 4** Jupiter is close above the Moon at nightfall, and outshines every other point of light in the sky at that hour.
- 6** Daylight Saving Time ends at 2 a.m. local time.

FEATURED EVENT

- 8** The Moon plunges through Earth's shadow, creating a total lunar eclipse.
- 8** Uranus (see page 22) is at opposition tonight. It rises at sunset, is visible all night, and shines brightest for the year. Even so, you will need binoculars or a telescope to pick it out, especially since it appears near the Moon.
- 9** Aldebaran is below the Moon as they climb into good view, in early evening.
- 10** Aldebaran is farther to the right of the Moon this evening, with brighter Mars rising close below the Moon and El Nath to the left of the Moon.
- 11** Mars appears to the upper right of the Moon as they climb into view.
- 13** Pollux, the brighter twin of Gemini, rises close above the Moon in late evening. Castor, the other twin, is to the upper left of Pollux.
- 16-17** Regulus, the heart of the lion, crouches below/to the right of the Moon at first light on these dates, respectively.
- 21** Spica stands to the upper right of the Moon at first light.
- 28-29** The Moon loops back around to Saturn, which is below/to the right of the Moon, respectively, at nightfall.
- 30** Jupiter is well to the left of the Moon at nightfall, with Saturn farther to the right of the Moon and Fomalhaut, the Autumn Star, below them.

NOVEMBER

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27	28	29	30	31		

NOVEMBER

FEATURED EVENT

A Perfect Alignment

For the third November in a row, Earth, Moon, and Sun will achieve syzygy—perfect alignment. The Moon will pass through Earth's dark inner shadow, the umbra, creating a total eclipse. At least part of the eclipse will be visible from the entire United States.

"Syzygy" comes from a Greek word that means a union, as when a pair of horses or oxen are yoked together. And several times each year, Earth, Moon, and Sun are locked in a precise alignment, resulting in either a lunar or solar eclipse.

Such alignments occur only at new Moon (in the case of a solar eclipse) or full Moon (for a lunar eclipse), so the shadow of Earth or the Moon falls on the other.

Eclipses aren't the only instances of syzygy in astronomy. Mercury and Venus can pass across the face of the Sun, for example. Neither planet is big enough to cover the Sun as seen from Earth, so, instead of eclipses, the events are known as transits. Astronomers also have used transits to discover thousands of planets in other star systems, as the planets pass directly in front of their home stars. And they have used another form of syzygy, known as an occultation (technically also an eclipse) to watch as a larger body passes in front of an apparently smaller one, as when the Moon or a planet covers up a distant star.

So syzygy is both an important tool for modern astronomy and a treat for casual skywatchers.



ECLIPSE OF NOVEMBER 8, 2022

- 3:09 a.m.** Partial eclipse begins as Moon first touches the umbra
- 4:16 a.m.** Moon fully immersed in the umbra; total eclipse begins
- 5:42 a.m.** Moon begins to leave the umbra; total eclipse ends
- 6:49 a.m.** Moon leaves the umbra; partial eclipse ends

All times are Central Standard Time

VIEWING FROM THE UNITED STATES

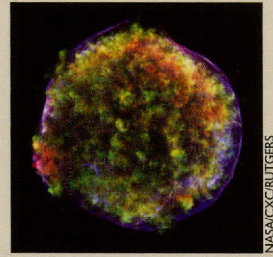
- The western third of the Lower 48 will see the entire eclipse, along with Alaska and Hawaii.
- From farther east, the eclipse will be in progress as the Moon rises. Most of the country will see the entire total eclipse but will miss the final stages of the partial eclipse.

KEY DATES

THIS MONTH IN HISTORY

November 11

Tycho Brahe observed a bright “new” star in Cassiopeia 450 years ago. He watched the star closely for months and published an extensive compilation of his work and that of others. The star showed that the heavens are not eternal and unchanging, as was believed at the time. Today, we know that Tycho was watching an exploding star, known as Tycho’s Supernova.



NASA/CX/RUTGERS

A modern-day X-ray view of the remains of Tycho’s Supernova

November 23

The Soviet Union’s final flight of its Moon rocket, N1, ended just like the three previous ones: with a big boom. The flight, which took place 50 years ago, was intended to send an unmanned command ship and a dummy lander past the Moon. A fuel line ruptured 90 seconds into the flight, though, causing the entire booster to explode a few seconds later. N1 development was cancelled soon afterward.

RESOURCES

ONLINE

StarDate

Daily skywatching tips, lunar phases, StarDate radio program, astronomy event listings stardate.org

SpaceWeather

Updates on solar flares and auroras, photo galleries, skywatching news spaceweather.com

Meteor Shower Calendar

International Meteor Organization www.imo.net/calendar/2022

Mr. Eclipse

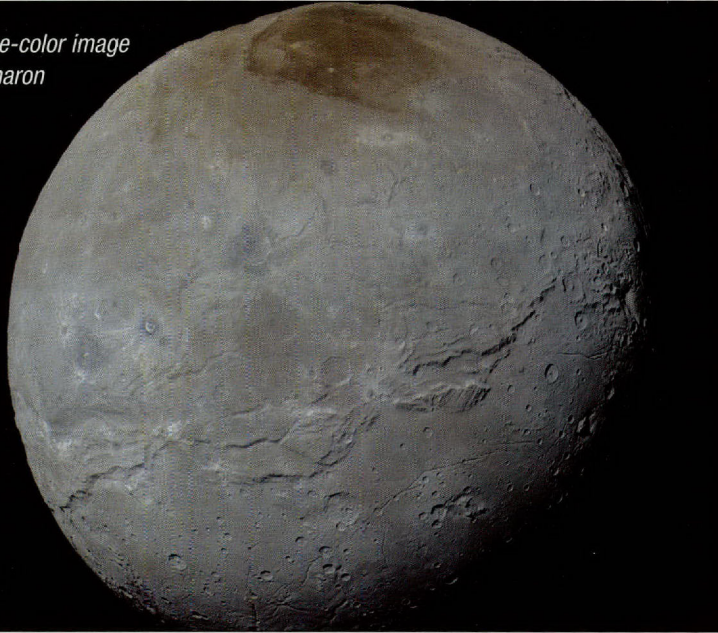
Details on eclipses for 2022 and beyond, plus historical eclipses www.mreclipse.com/main/preview.html

BOOKS

Observer’s Handbook 2022, Royal Astronomical Society of Canada rasc.ca/handbook

Yearbook of Astronomy 2022, edited by Brian Jones casemateipm.com/yearbook-of-astronomy-2022.html

A true-color image of Charon



NASA/JHUAPL/SWRI/ALEX PARKER

Hefty Moon with a Red Beanie

On its own, Charon the largest moon of Pluto, isn’t all that impressive—it’s only the twelfth-largest moon in the solar system. Relative to its host, however, it’s the largest—a bit more than half the diameter and one-eighth the mass of Pluto itself. And because of Charon’s relative heft, Pluto and Charon are locked so that the same hemisphere of one always faces the same hemisphere of the other, just as the same side of the Moon always faces Earth. It’s the only parent-moon pairing in the solar system where that’s the case.

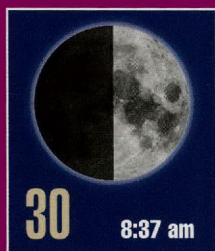
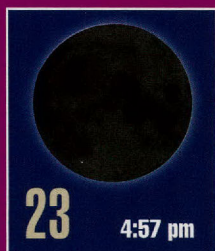
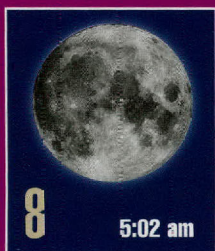
Scientists have pondered the origin of Charon since its discovery, in 1978. For a long time, the leading theory said that Pluto was hit by another large body early in its history, blasting debris into orbit around Pluto. Much of the debris quickly stuck together to form Charon.

When the New Horizons space-

craft flew past Pluto and Charon in 2015, though, it found that their chemistry didn’t match such an origin scenario. Today, the smart money is on an early collision between Pluto and Charon, which were orbiting the Sun independently of each other. The impact was strong enough to blast away some of their outer layers but not to rip them apart. They then settled into a mutual orbit around each other.

Most of Charon is dark gray, marked by ice cliffs and impact craters. It’s topped, however, by a patch of red. It’s an amalgam of nitrogen plus methane and other organic compounds. They probably immigrated from Pluto with clouds of other, lighter materials. The lighter materials eventually vaporized into space, leaving the organic compounds, where were reddened by exposure to solar radiation—leaving Charon topped by a red beanie.

Moon phases are Central Time.



The full Moon of November is known as the Frost Moon or Snow Moon.

APOGEE
November 14

PERIGEE
November 25

OVERVIEW

Mars shines at its most brilliant this month as it reaches opposition. The bright orange planet is in view all night. Venus and Mercury spend most of December huddled together in the evening twilight, with Mercury changing brightness significantly during the month. The stars of winter begin to take over the evening sky, with Orion climbing across the south, trailed by Sirius, the brightest star in the night sky.

HIGHLIGHTS

1-2 Brilliant Jupiter stands close to the upper left/farther to the upper right of the Moon at nightfall, respectively.

6 Aldebaran is close below the Moon at nightfall, with brighter Mars farther to the lower left of the Moon.

FEATURED EVENT

7 Mars is at opposition and is occulted by the full Moon.

10 Pollux, the brighter twin star of Gemini, is close to the left of the Moon as they climb into view in mid-evening.

13 The Geminid meteor shower should peak this morning.

13 Regulus rises close to the lower right of the Moon, before midnight.

18 Spica stands close below the Moon at first light.

21 Winter arrives in the northern hemisphere at 3:48 p.m. CST, the moment of the December solstice. It is the shortest day and longest night of the year in the northern hemisphere, and the Sun stands farthest south in the sky.

24 Mercury and Venus pose to the right of the Moon in the evening twilight, quite low in the southwest. Venus is the Evening Star.

26 The planet Saturn stands to the right of the Moon at nightfall.

27 Mercury is above Venus, the Evening Star, in the early evening twilight. Mercury is about one-fortieth as bright as Venus.

28-29 Jupiter stands to the upper left/to the right of the Moon at nightfall, respectively.

DECEMBER

Su	M	T	W	Th	F	Sa
				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

DECEMBER

FEATURED EVENT

Mars Blazes, Mars Vanishes

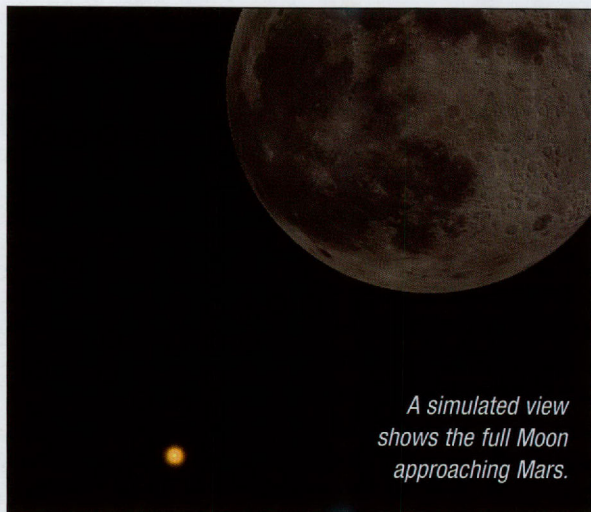
Mars is at its biggest and boldest early this month. The planet is at opposition on December 7, which means it aligns opposite the Sun. It rises at sunset, remains in view all night, and is closest to Earth for the year, so it shines at its brightest. For a while, in fact, it will be the fourth-brightest object in the night sky.

At the moment of opposition, though, Mars will be missing from view from most of the United States. Another object at opposition—the full Moon—will occult the Red Planet, blocking it from view.

Although Mars won't shine this bright again until early 2025, this is only a so-so opposition. Mars follows a lopsided orbit, so its distance to the Sun varies by tens of millions of miles. When opposition occurs in the summer, Mars is closer to the Sun than average, which means it's closer to Earth than average—as little as about 36 million miles (58 million km)—so it shines especially bright. When opposition occurs during late fall or winter, though, Mars is farther from the Sun, which means it stays farther from Earth as well. This month, for example, it will pass no closer than 50.6 million miles (81.5 million km) from Earth.

It's just a coincidence that Mars and the Moon will reach opposition at almost the same moment. The Moon circles past Mars roughly once per month. As with lunar and solar eclipses, though, the geometry is usually a little off for an occultation. Their orbits are tilted at different angles, so they don't always overlap. The geometry has to be just right for the Moon to pass in front of Mars.

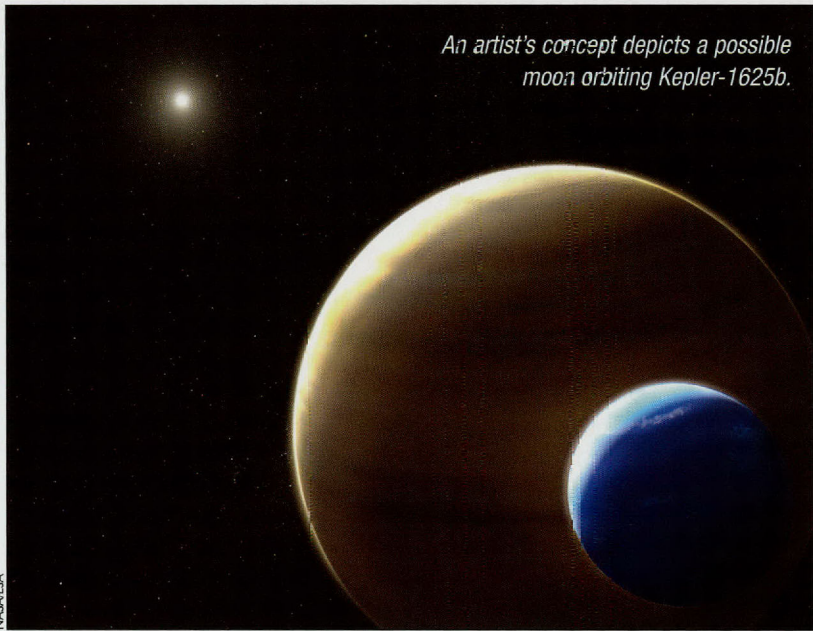
This occultation will be visible from all of the United States except the southeast, Hawaii, and most of Alaska. At most, the Moon will cover Mars for a little more than an hour. Before and after the occultation, Mars will look like a bright star, although the moonlight may bleach its normal orange color—draining a bit of drama from its best showing of the year.



A simulated view shows the full Moon approaching Mars.

STELLARUM

An artist's concept depicts a possible moon orbiting Kepler-1625b.



NASA/ESA

An Absence of Exomoons

In our own solar system, planetary moons are as common as fleas on a stray dog—Jupiter alone has more than 80. Yet not a single confirmed moon has been found in any other star system, even though astronomers have discovered thousands of exoplanets. There are hints of moons in a few systems, and evidence that moons are taking shape in another.

Scientists are particularly interested in moons because they might provide habitable environments for life even if their parent planets do not.

Moons are an inevitable consequence of just about every model of planet formation. Exomoons are extremely difficult to find, however, because they are small and faint.

In 2018, observations by the Kepler space telescope and Hubble Space Telescope revealed a possible Neptune-sized moon orbiting the giant planet Kepler-1625b, although the discovery has not been confirmed.

A 2020 study reported evidence of eight moons orbiting planets discovered by Kepler. The planets cause their parent stars to dim slightly as they pass in front of the stars. The timing of those passages appears to vary a bit, perhaps as the result of the pull of orbiting moons.

And a 2021 study found that moons could be taking shape around PDS 70c, a planet orbiting a star about 370 light-years away. The planet, which is still taking shape, is encircled by a disk of dust grains. The disk contains about 2.5 times the mass of the Moon, so there is plenty of material to make one or more moons. And the planet and its disk are pulling in even more material from a larger disk that surrounds the star.

Giant new ground- and space-based telescopes and other new technology should make it easier to find exomoons in the years ahead.

KEY DATES

December 17

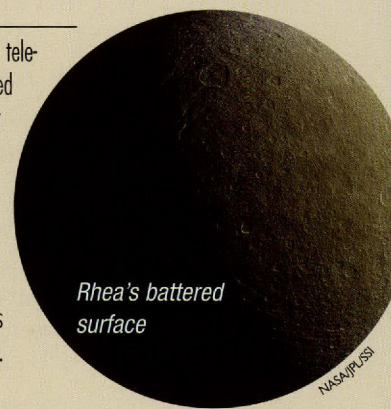
CALENDAR EVENT

Today is Saturnalia, one of several ancient festivals tied to the winter solstice. This Roman event honored Saturn, the god of the harvest. People decorated trees with sweets and ornaments, performed acts of charity, exchanged gifts, and decorated their houses with candles and lamps. Many of Saturnalia's customs survive in the celebration of Christmas.

THIS MONTH IN HISTORY

December 23

Giovanni Cassini, a pioneer in the telescopic study of Saturn, discovered Rhea, the planet's second-largest moon, 350 years ago. (The moon wasn't formally named, for the wife of Cronus, the Greek name for Saturn, until 1847, however.) Rhea's surface is battered by impact craters and marked by long cracks that reveal bright layers of ice below.



Rhea's battered surface

NASA/JPL/SSI

THE BASICS

Moons of the Solar System*

Earth	1	Uranus	27
Mars	2	Neptune	14
Jupiter	79	Pluto	5
Saturn	82		

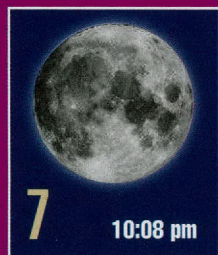
* As of December 2021

Largest Moons

MOON	DIAMETER**	PLANET
Ganymede	3,274/5,268	Jupiter
Titan	3,200/5,150	Saturn
Callisto	2,995/4,821	Jupiter
Io	2,264/3,643	Jupiter
Moon	2,159/3,475	Earth

** Miles/Kilometers

Moon phases are Central Time.



The full Moon of December is known as the Long Night Moon or Moon Before Yule.

APOGEE
December 11

PERIGEE
December 24

Evening Venus Shines at its Best

Bright planets abound in January and February. Venus and Jupiter are in the southwest during the early evening in early January, with Venus moving to the morning sky by mid-month. Mercury also does evening/morning double duty in January. And Deneb, the bright star at the tail of Cygnus, the swan, is visible both evening and morning for most of the period—low in the northwest in the evenings, and in the northeast in the mornings.

JANUARY 1-15

You probably know a lot about atmospheric extinction even if you've never heard of it.

It's what makes the setting Sun so much dimmer than the Sun high up. That happens because there's much more atmosphere along your line of sight to an astronomical object near the horizon. The same dimming happens not just to the Sun and Moon, but to stars, planets, nebulae, and all the rest.

An example awaits you among the two bright planets shining in the southwest at dusk in the last week of December and the first day or two of January.

Look fairly high in the southwest 30 or 40 minutes after sunset, as twilight fades. There's Jupiter, the first "star" in that part of the darkening sky. Now look way down to Jupiter's lower right, by three or four fists at arm's length, for brighter Venus near the horizon.

Did I say brighter? On paper, Jupiter on January 1 is magnitude -2.1 and Venus is -4.2 . That difference of 2.1 magnitudes means Venus is seven

times brighter than Jupiter. And that's indeed how they would look if Earth had no air.

But extinction increases fast

it will look less than half as bright as Jupiter, not seven times brighter! Binoculars will help you compare them through the twilight.

And that's in clean, clear air. Any haze or dust in the air will dim Venus further compared to Jupiter.

While you're looking southwest, two fainter planets also await you. Look two fists to the lower right of Jupiter and there's Saturn, about seven percent as bright as Jupiter while still fairly high. To the

tude are changing daily, so no numbers here.

Mercury is on its way up to a fine but brief evening showing in the second week of January, approaching but never quite reaching Saturn.

JANUARY 16-31

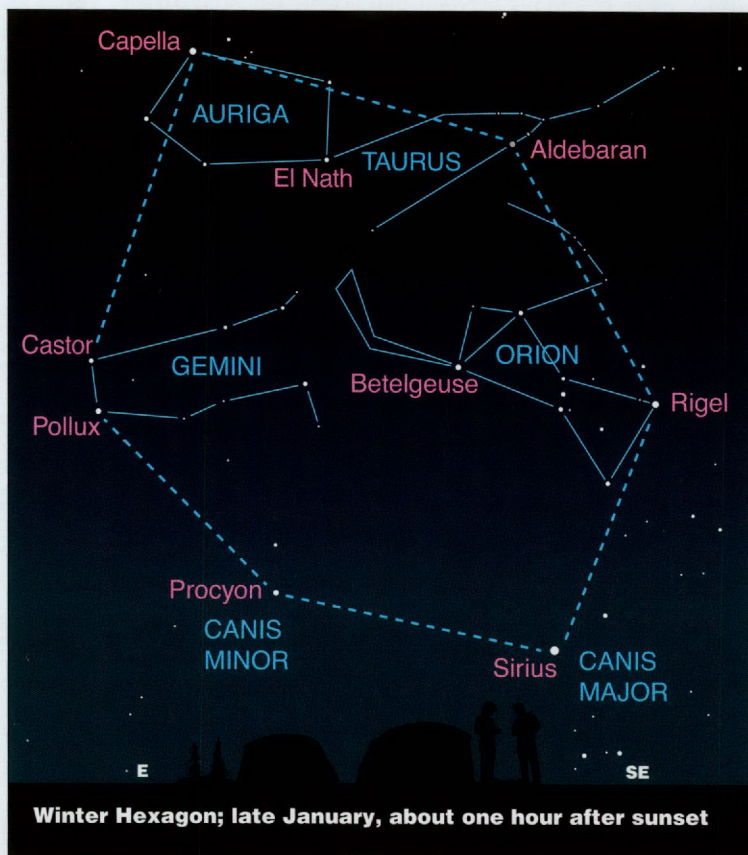
Venus is gone. Mercury and Saturn linger as specks just above the west-southwestern horizon in twilight until about January 18, then they're also gone. Above them, Jupiter shines on, but it sets roughly an hour after full dark.

But turn around and look southeast! The whole Orion family of constellations shines high and proud there.

Orion himself strides high at the center, with his three-star belt starting to tilt a bit. The belt points down to dazzling Sirius, the dog tag on the chest of the stick figure that is Canis Major, the big dog, who always follows in Orion's footsteps. To the upper left of Sirius is Procyon, the light of Orion's other dog, Canis Minor.

Along with orange Betelgeuse, in Orion's shoulder, Sirius and Procyon form the equilateral Winter Triangle. The triangle's inside is filled mostly with dim Monoceros, the unicorn—also part of the family.

Lepus, the hare, crouches below the hunter's feet. Near Rigel, Orion's bright, stamping front foot, springs the start of Eridanus, the river Euphrates, which winds back and forth on its way far south, down to the horizon. And



as an object approaches the horizon. Forty minutes after sunset, Jupiter remains high, but Venus is only about four degrees above the true horizon (depending on your location). So if you can see Venus,

lower right of Saturn, and the upper left of Venus, is Mercury. It's officially brighter than Saturn, but again atmospheric extinction is in play, so it may look dimmer. Mercury's height and intrinsic magni-

above or to the upper right of Orion, big Taurus eternally backs away from the hunter's upraised shield and club (both of which are dim). Taurus glares down with his fiery bull's eye Aldebaran, while the Pleiades cluster shimmers over his back, near the zenith.

Betelgeuse is Aldebaran-colored but brighter. Betelgeuse is famous as the brightest "red" supergiant star in the sky, but you'll see that it's not red but pale orange or even yellowish; astronomers use the term "red" loosely to mean anything on the long-wavelength side of white. Similarly, people who've always heard Mars called "the Red Planet" are often confused to see that Mars is not traffic-light color but candle-flame color. When space artists paint red-giant stars like red rubber balls, you can tell they don't know their astronomy.

Rigel, by contrast, is a white supergiant, or perhaps white with just a trace of icy blue.

Rounding out Orion's main stars are Bellatrix, which represents his other shoulder, and Saiph, his other foot. These and his three belt stars are blue-white giants.

All seven of Orion's leading stars, being super-luminous, are quite young, astronomically speaking. Their estimated ages range from six million years for the two upper belt stars to 25 million years for Bellatrix. That's still well less than one percent of the age of the Sun and solar system.

FEBRUARY 1-14

Jupiter is going the way of all planets, which is to periodically pass from sight into the glare of the Sun. On February 1, Jupiter remains about a fist-width at arm's length above the west-southwestern horizon an hour after sunset, as twilight is getting late. But it appears lower every evening, and by the 15th it's basically

gone. Jupiter will reappear out of the other side of the Sun's glare come April, low in the dawn.

But Venus has already gotten there! Look southeast just as dawn begins in February, and there's the bright Morning Star shining low. It climbs higher day by day.

Other planetary action is happening around Venus. When dawn is just beginning (about an hour and 15 minutes before your local sunrise), look for tiny little Mars near Venus. It's nearly a fist to the right of Venus in the first few days of February, then closer to the lower right after that. Because it's on the far side of its orbit, Mars is faint, at magnitude 1.4, so binoculars will help if the sky is getting too light.

Binoculars also will help you pick up Mercury, shyly emerging way down below Venus and Mars in the second week of February. Look for Mercury about a fist and a half to the lower left of Venus by then, as dawn brightens.

Back in the evening sky, Orion now stands upright at his highest in the south as

early as 8 p.m. To the left or upper left of Orion, as you face southeast in early evening, is his neighbor Gemini. The twins are not usually considered part of the Orion family; their legends are unrelated. The twins' starry stick figures are still lying on their sides, with their heads, Castor and Pollux, on the far end from Orion.

And Capella, the brightest star of Auriga, shines nearly overhead. Whenever Orion's front foot, Rigel, is due south, Capella is at its closest to the zenith.

FEBRUARY 15-28

"Asterism" is the term for an informal constellation, the kind anybody can invent. Sometimes people's off-label creations catch on and stick, such as the Big Dipper, the Sagittarius Teapot, the Great Square of Pegasus, and the Sickle of Leo. Numerous amateur astronomers have posted more than a thousand favorite asterisms they've found—naked-eye, binocular, and telescopic. There's the Leaping Minnow, Stargate, Kemble's Cascade, Jaws, the Broken En-

Close Sun, Cold Days

Earth huddles closest to the Sun for the year on January 4. Known as aphelion, this close passage takes place every January. The Sun will be just 91.4 million miles (147.4 million km) away, which is about 1.5 million miles (2.4 million km) closer than average.

The distance between Earth and the Sun changes because Earth's orbit is an ellipse, which looks like a slightly flattened circle. When the Sun is closest, we receive about seven percent more total solar energy than when it's farthest, in early July. But that has nothing to do with the seasons, which are

controlled by Earth's tilt on its axis. In early January the north pole is tilted away from the Sun, so it's winter in the northern hemisphere and summer in the southern hemisphere.

The changing distance does have one important impact on the seasons. When Earth is close to the Sun, it moves faster in its orbit than when it's farther away. That makes the length of the seasons uneven. In the northern hemisphere, winter is only about 89 days long, compared to 93 days for summer—extra sunlight thanks to our lopsided orbit around the Sun.

Meteor Watch

The Shower Quadrantids

Named for the extinct constellation Quadrans Muralis, the wall quadrant, an early astronomical instrument. Today, that region is part of Boötes the herdsman.

Peak Night of January 2/3

Notes

The Quadrantids produce a large number of meteors at their peak, but the peak lasts only a few hours, providing a short viewing window. The Moon is new, so it won't interfere with the fireworks.

gagement Ring, Orion's S, the Taurus Spray... Sudor Ophiuchi, the Sweat of Ophiuchus, flies off his shoulder as he wrestles Serpens, the snake. Most of these probably will be forgotten, but some seem to be entering the canon.

Now filling the southern sky is the largest asterism that's widely recognized: the Winter Hexagon (or circle). Start with brilliant Sirius, the hexagon's bottom point. Draw a line to the upper left from there to Procyon, then up to Pollux and Castor, across the overhead area through faint Beta Aurigae to bright Capella, down to Aldebaran, then Rigel, and back to Sirius. The hexagon isn't perfect; it's somewhat taller than wide, elongated along its Sirius-Capella axis.

Betelgeuse shines inside the hexagon, well off center. Take the segment from Aldebaran to Capella, twist it to go from Aldebaran to Betelgeuse instead, and now you've got the Heavenly G. As the evening progresses, the G rotates to read nicely upright.

Alan MacRobert is a senior editor of Sky & Telescope.

JANUARY

How to use these charts:

1. Determine the direction you are facing.
2. Turn the chart until that direction is at the bottom.

December 20

11 p.m.

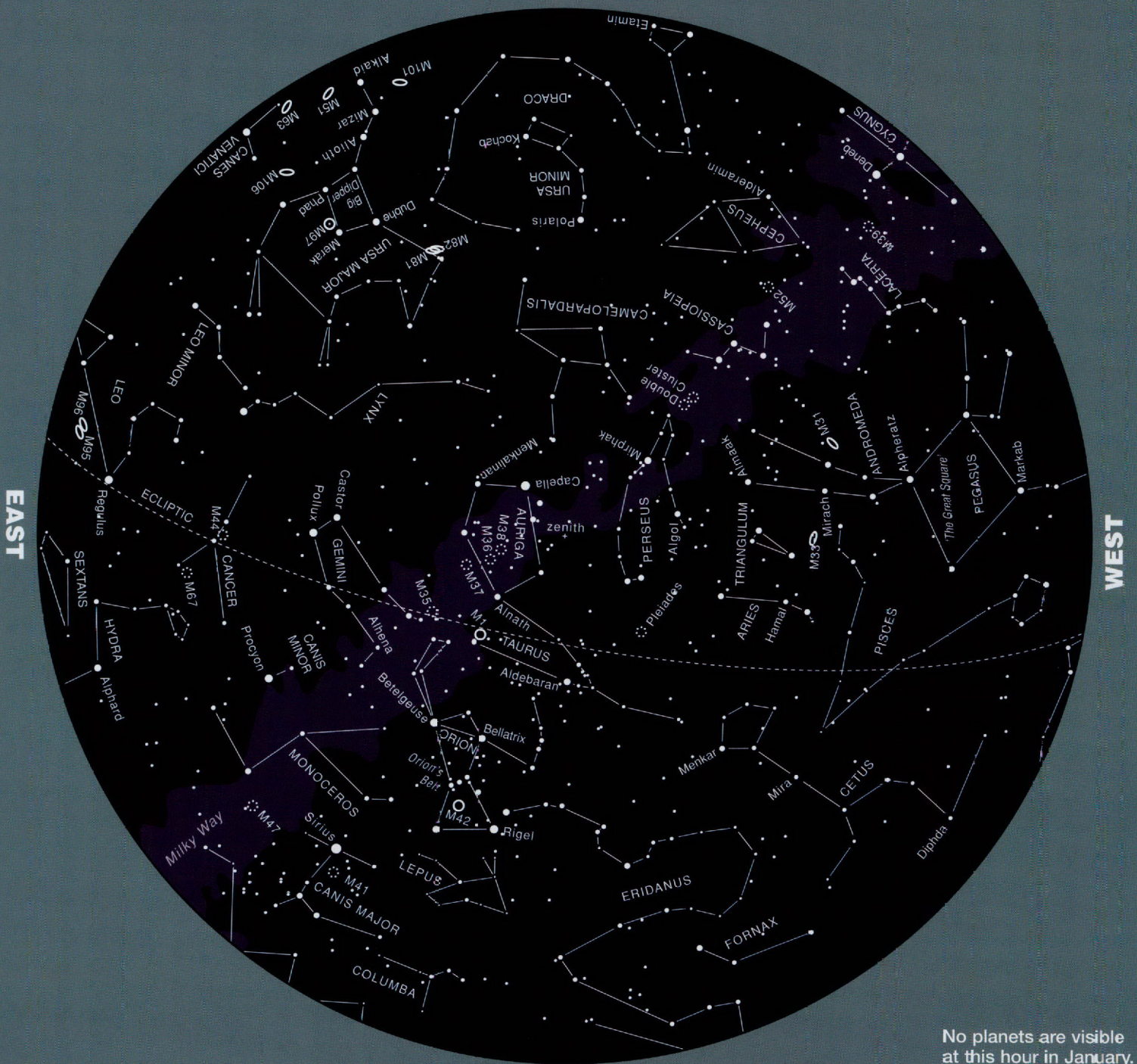
January 5

10 p.m.

January 20

9 p.m.

NORTH



EAST

WEST

MAGNITUDES

- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

SOUTH

No planets are visible at this hour in January.

- ⊙ open cluster
- ⊙ globular cluster
- ⊙ nebula
- ⊙ planetary nebula
- ⊙ galaxy

FEBRUARY

How to use these charts:

1. Determine the direction you are facing.
2. Turn the chart until that direction is at the bottom.

January 20

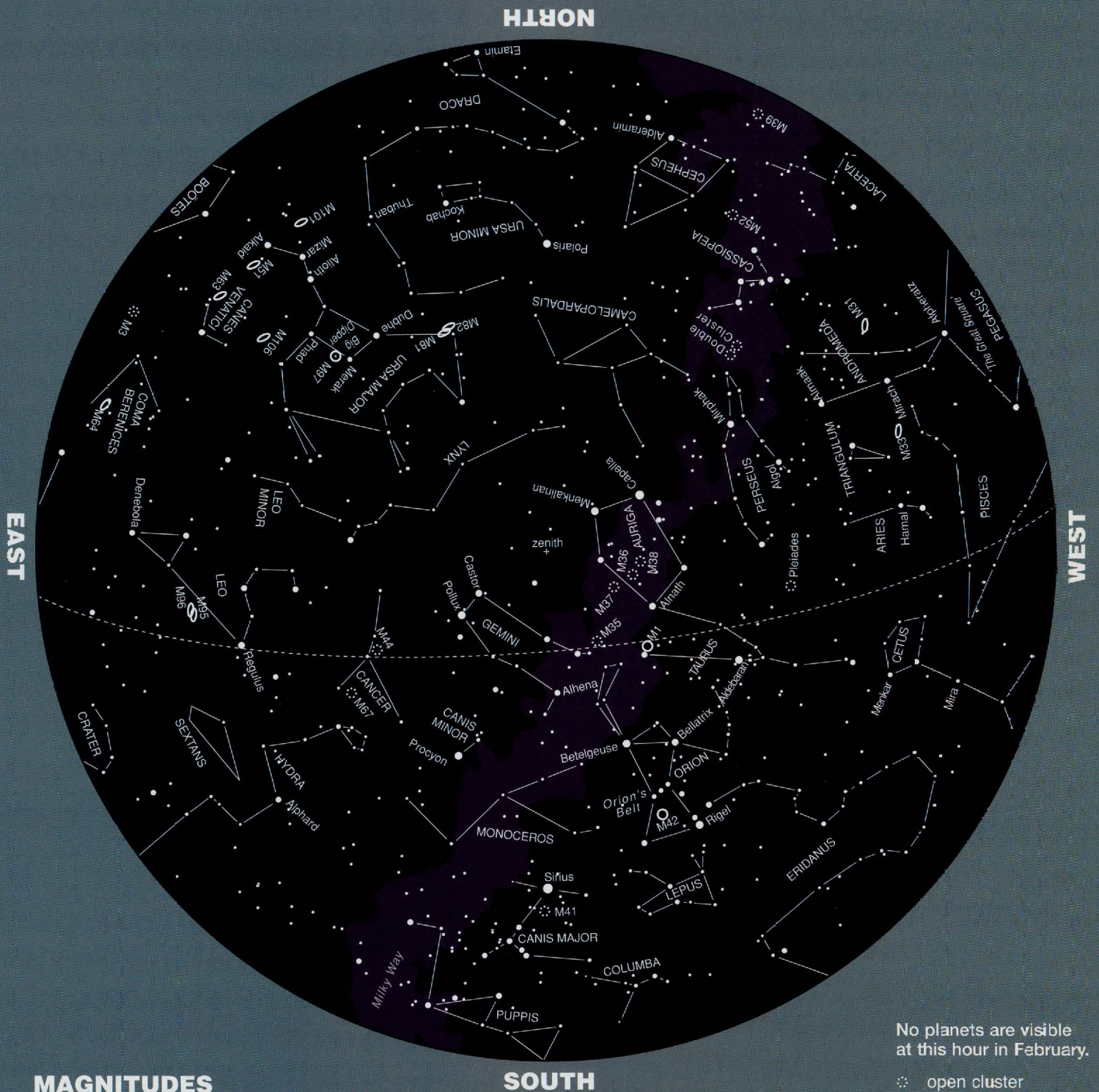
11 p.m.

February 5

10 p.m.

February 20

9 p.m.



MAGNITUDES

- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

No planets are visible at this hour in February.

- open cluster
- ⊙ globular cluster
- nebula
- planetary nebula
- galaxy

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