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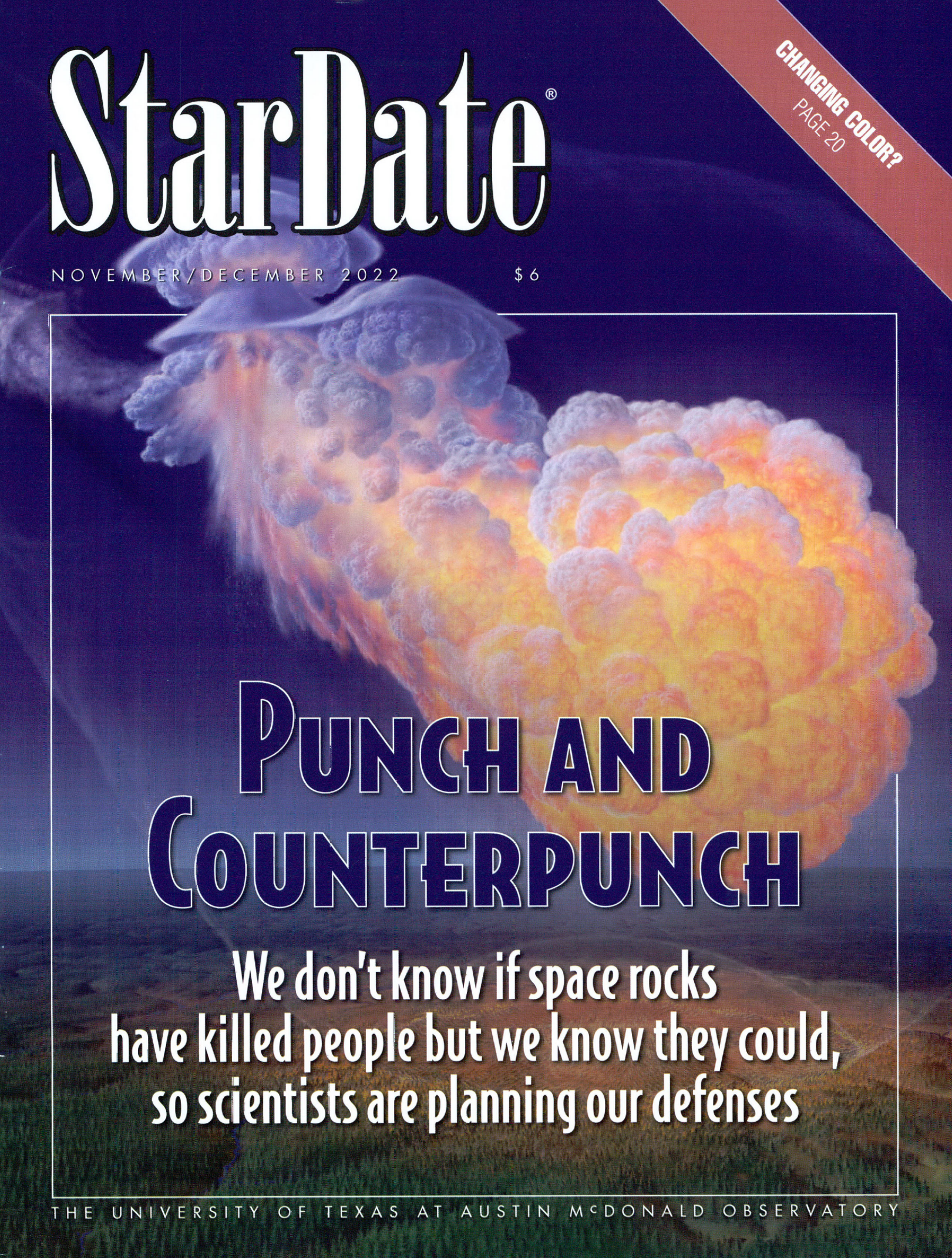

PUNCH AND COUNTERPUNCH

We don't know if space rocks have killed people but we know they could, so scientists are planning our defenses

THE UNIVERSITY OF TEXAS AT AUSTIN McDONALD OBSERVATORY

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Features

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On The Cover

An asteroid explodes above Tunguska in 1908, producing a brilliant fireball and towering clouds, in this artist's concept. The blast may have killed several people. See more starting on page 4.

This Page

A massive star in the early universe explodes as a supernova in this artist's concept. The star could have been 300 times the mass of the Sun, which is much larger than any stars in the present-day universe. Although astronomers have never observed such a star or its death as a supernova, they may have found the aftermath of one in clouds of gas and dust in a distant galaxy.

Coming in January

Our 2023 Sky Almanac issue will bring you all the details on what to look for in the night sky, plus a solar eclipse in the daytime sky in October. And since 2023 will mark our golden anniversary, we'll recall 50 years of progress in astronomical science and technology.

NOIRLAB/NSF/AURA/J. DA SILVA/SPACEENGINE

MERLIN

Dear Merlin,

If the universe is constantly expanding in all directions at a super-fast speed, why are things in our solar system so relatively constant in terms of distances, orbits, and gravitational effect? You'd think that with galaxies flying all over the place, the gravitational forces of the Sun, other planets, and other galaxies would change our solar system just a bit.

Stephen Harty
Irvington, New York

Actually, you hit on the key phrase in your first sentence: relatively constant. The distances and orbits of the solar system's planets, comets, and asteroids are pretty stable now, but they haven't always been so.

Gravitational interactions among the planets when the solar system was young pushed all of the planets around. Jupiter and Saturn moved inward, with Jupiter sliding about as close to the Sun as Mars is today, then back out to their current positions. Jupiter's gravity stirred up material in the present-day asteroid belt, preventing it from coalescing to form a larger body. And the slip-sliding of the giant outer planets could have pushed some planets into the Sun, with Earth and its fellow rocky worlds perhaps forming afterwards.

The effects aren't as pronounced today as they were in the solar system's early days, but the planets (especially the bigger ones) still create long-term changes in each other's orbits.

The expansion of the universe is, well, a universal phenomenon as a result of the Big Bang. Space itself is expanding, pushing galaxy clusters farther apart. The expansion is insignificant on the scale of individual galaxies or smaller, so the solar system experiences none of it. Over the eons, though, as the expansion continues to accelerate, individual galaxies will move away from each other faster than the speed of light, so the inhabitants of each galaxy will see only their own "island universe," with every other galaxy hidden in the cosmic darkness.

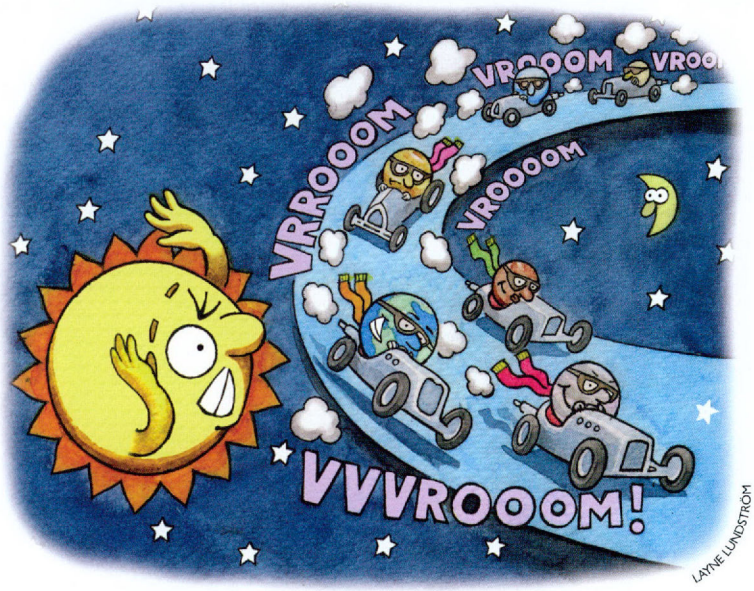
Dear Merlin,

Dark matter makes up a significant percentage of the mass in the universe. Recently, researchers announced finding some galaxies that appear to contain no dark matter. How can this be?

James Machin
Austin

Scientists are asking themselves that same question.

For some background, dark matter produces no detectable energy, so astronomers can't see it. But it exerts a gravitational pull on the visible matter around it, so they know it's there, accounting for 85 percent of all the matter in the universe. As with the Sun in the previous answer, that's a lot of gravity.



Dark matter is thought to have provided the gravitational "seeds" that pulled normal matter together to form galaxies, but a few galaxies appear to have little or no dark matter at all.

That could mean that dark matter isn't as evenly spread as thought or that the dark-matter-free galaxies formed in regions were there just happened to be unusually high concentrations of normal matter. One recent idea says the galaxies formed with lots of dark matter then rammed into other galaxies at high speeds. The normal matter stopped cold, while the dark matter just kept going—leaving some unusual galactic remnants.

Dear Merlin,

If gravity is the weakest of the four fundamental forces, how can the Sun's gravity affect such distant and relatively low-mass objects as those in the Kuiper Belt and Oort Cloud?

Neal Attinson
Sonoma, California

Because the Sun has a lot of gravity.

You are correct that gravity is extremely weak compared to the other forces of nature. The electromagnetic force, which gives us visible light, X-rays, magnetism, and much more, is about 10^{36} times stronger—a one followed by 36 zeroes. Still, it adds up. Pack enough matter into a small enough space and its gravitational pull becomes impressive.

Think of it like cotton candy. You can carry a single serving of cotton candy while you stroll the grounds at the state fair. Make the serving a mile high, though, and it will crush you. The Sun is the equivalent of that jumbo serving, so its total gravitational pull is strong.

Keep in mind that objects like those in the Kuiper Belt, beyond the orbit of Neptune, can be perturbed by the gravity of the giant outer planets or even other objects in the Kuiper Belt. And the balls of ice and rock in the Oort Cloud, barely held by the Sun's gravitational grip, can be flicked away by other stars that are light-years from the Sun.

Merlin is unable to send personal replies. Answers to many astronomy questions are available through our web site:

stardate.org/astro-guide

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KILLER ASTEROIDS

Many stories say falling meteorites or exploding asteroids or comets have been killers. There's just not a lot of proof.

By Damond Benningfield

NIKITA PLEKHANOV/WIKIPEDIA

The trail left by the Chelyabinsk asteroid twists across the sky. Above: Glass shards litter the floor of a theater after the airburst blew out many of its windows. Top: The Tunguska airburst flattened millions of trees.

For the sparse population near the Tunguska River in Siberia, June 30, 1908, started like countless other days. The Evenki natives slept, prepared their breakfasts, or tended their reindeer herds in the heavily forested Evinkiysky district, anticipating a warm day ahead. At about 7:14 a.m., though, their world exploded. A bluish point of light appeared in the sky, followed by a flash as bright as the Sun, a tower of fire, an angry cloud, and a roar that made some think it was the end of the world. A shockwave blasted the landscape, destroying huts and slamming their residents into walls or trees—some with enough force to break bones.

"The Earth began to move and rock, the wind hit our hut and knocked it over," one survivor told investigators years later. "Then I saw a wonder: trees were falling, the branches were on fire, it became mighty bright, how can I say this, as if there was a second sun, my eyes were hurting, I even closed them. ... And immediately there was a loud thunderclap."

It took scientists a long time to understand what happened, and they still debate the details today. Most, however, say the likely cause of the pyrotechnics was a building-sized space rock or iceball that hit Earth's atmosphere at high speed, exploding with the power of a large nuclear bomb several miles above the surface. The blast was visible hundreds of miles away, and the shockwave flattened 80 million trees across half a million acres. And it appears to have killed three people and maybe more—possible victims of an extraterrestrial visitor.

In fact, the Tunguska event is considered one of the most solid cases of death-by-space-rock. Although the Evenki people had no written language, they were interviewed by experts from Russia who compiled detailed records of their accounts. Combined with the physical evidence, they tell a tale of a remarkably destructive event—one with enough power to destroy a city.

Tunguska is far from the only story of deaths caused by exploding asteroids or comets or by falling meteorites, however. Records from ancient China log several deadly events, including a "rain of iron" that killed thousands, and incidents with smaller death tolls were reported elsewhere. Many scientists doubt the veracity of such reports, however, in part because there's little or no physical evidence, such as impact craters or surviving meteorite fragments.

And some recent studies have suggested that many people could have died in Tunguska-like airbursts in North America and the Middle East. Those studies are highly contested by experts in asteroids, atmospheric explosions, and other fields, however. That leaves the total number of universally accepted asteroid or meteorite victims at precisely ... zero.

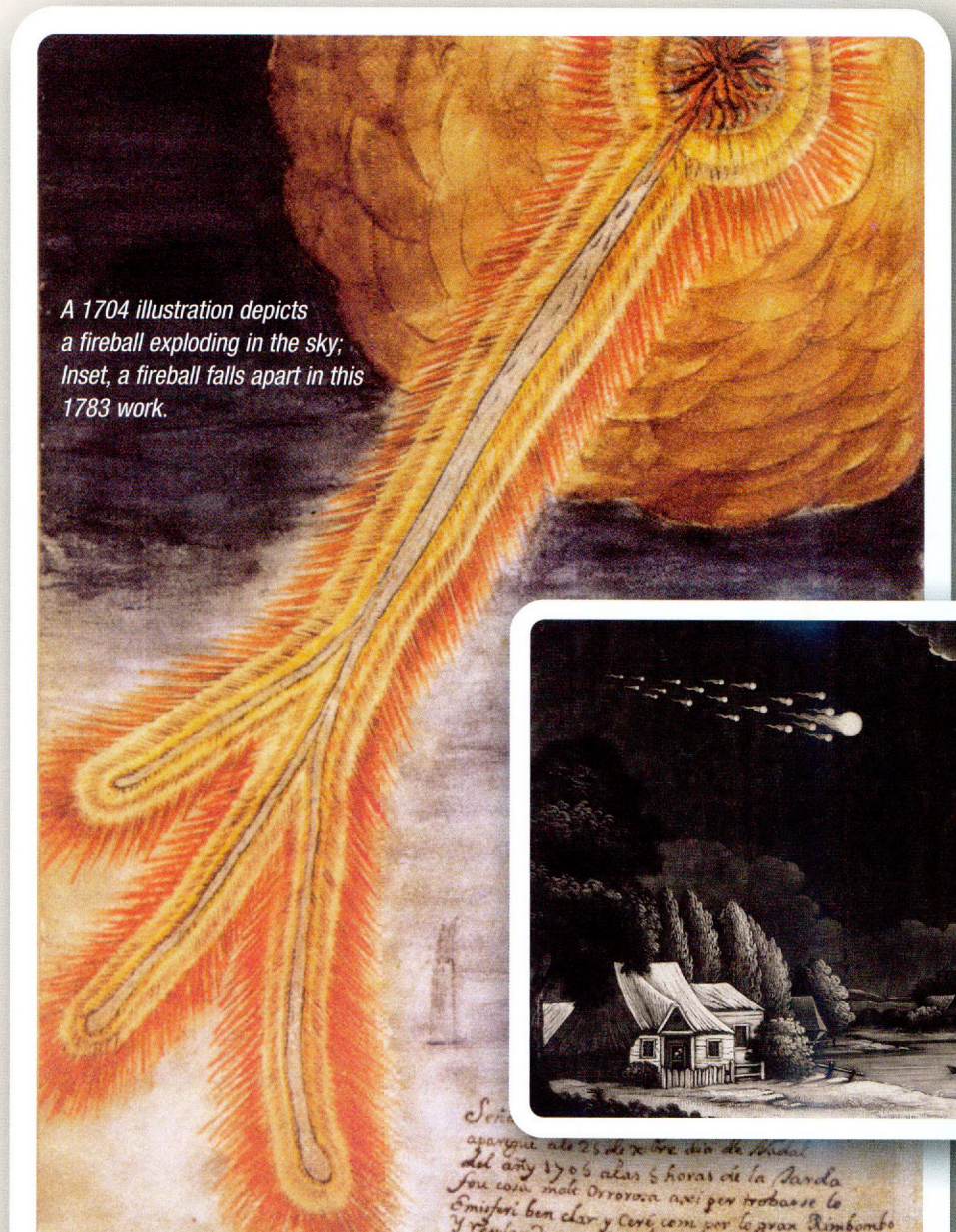
"Tunguska is probably the best attempt to nail it down, but there's still an element of ambiguity," says Mark Boslough, a research professor at the University of New Mexico and an expert in atmospheric explosions and asteroid impacts. "It wouldn't be a surprise if one or more people were killed, but it's not a slam dunk."

Asteroids are chunks of rock, metal, and ice that orbit the Sun. The vast majority reside in the asteroid belt—a wide band of debris between the orbits of Mars and Jupiter. Astronomers have cataloged more than 1.2 million of them, with all but a few thousand discovered in the past three decades—largely as a result of efforts to find the dangerous ones (see page 16). Their icy cousins, comets, are far less numerous in the inner solar system but perhaps more dangerous because they can approach from deep space from almost any direction, providing little warning.

Occasionally, a collision in the belt kicks an asteroid, or at least asteroid chips, spiraling toward the Sun. Such objects can come close to Earth, setting up a possible conflict. Astronomers have discovered 30,000 near-Earth objects (NEOs), whose orbits bring them within a few million miles of Earth's orbit. Of those, the orbits of about 2,200 cross Earth's, earning them their own category: potentially hazardous objects. (All but a handful of both categories are asteroids.) Astronomers keep a close eye on them, constantly refining predictions of their orbits to alert us of possible impact risks.

Smaller asteroids—no bigger than a small office building—are too faint to detect until they pass close to Earth, so we don't see them until the last minute. In fact, automated searches have discovered several small asteroids just hours before they hit our planet. Fortunately, they burned up in the atmosphere, creating some fireworks but causing no harm.

Some of the little guys are large enough to shower the surface with chunks of rock, which could injure or kill people or other creatures unlucky enough to get



A 1704 illustration depicts a fireball exploding in the sky; Inset, a fireball falls apart in this 1783 work.

XAVIER CABALLÉ

hit. One of the most celebrated meteorite events in history took place in Alabama in 1954, when a rock punched through the ceiling of a house, bounced off a radio, and slammed into the leg of Ann Hodges, giving her a giant bruise and instant celebrity.

Asteroids the size of larger buildings can explode with the power of nuclear bombs, creating deadly shockwaves and fires and causing other mayhem. And the largest, densest asteroids can plunge all the way to the surface, gouging craters and sterilizing huge swaths of landscape.

Those realizations didn't come easily, however, and the complete picture didn't solidify until the 1960s.

Many early civilizations thought of rocks that fell from the sky as gifts from the gods, so meteorites became objects of worship. (A meteor is a streak of light created as a space rock burns up in the atmosphere, while a meteorite is a piece that survives the plunge and hits the surface.) Early investigations explained them as volcanic rocks (and some sky-falling rocks do have volcanic origins), condensations from the upper atmosphere, or other terrestrial phenomena.

Ernst Chladni, a German physicist who made his reputation studying acoustics, and even invented some odd musical instruments, was the first scientist to study meteors and meteorites in a rigorous manner, in the 1790s. He concluded they came from beyond Earth, perhaps as debris from destroyed planets or as material that never coalesced to form a planet. Although initially sneered at by other scientists, the idea gained acceptance after other studies, including chemical analyses of the odd rocks, supported Chladni's conclusion.


HENRY ROBINSON

Most meteorites fall as single rocks or small clumps. A few falls, however, shower the landscape with thousands of fragments as one or more larger rocks disintegrate.

The largest cosmic hailstorm yet recorded dropped perhaps 70,000 meteorites outside the Polish town of Pultusk, near Warsaw, on January 30, 1868. Thousands of people saw a brilliant fireball streak across the sky, explode, then rain rocks across a wide area. The largest fragment weighed about 20 pounds, although most were no bigger than peas. Many meteorites hit houses, but there were no reports of any hitting people, much less killing anyone.

Another major storm hit near Holbrook, Arizona, on July 19, 1912. It began with "a heavy explosion similar to that of a heavy blast, followed by a fusillade of smaller explosions which terminated in a thunder-like rumble of approximately two minutes duration," reported the *Holbrook News*. "The volume of the explosion can be best judged by the fact that it was heard ... about one hundred miles north and south of Holbrook." About 14,000 fragments were recovered within days or weeks. Residents saw several of the fragments hit the ground but, as with Pultusk, no one was injured.

The people of Chelyabinsk, a city of more than one million in the Ural Mountains of southwestern Russia, were less fortunate. On the morning of February 15, 2013, a roughly 13,000-ton, 65-foot (20-meter) asteroid streaked across the southern sky. Hitting the atmosphere at an estimated speed of more than 40,000 miles per hour was almost like pancaking into a granite mountain. The pressure caused the asteroid to explode high in the sky with the equivalent of up to 500 kilotons of TNT—more than 30 times the power of the atomic bomb that destroyed Hiroshima.

A shockwave slammed into the city, damaging more than 7,000 buildings. Almost 1,500 people sought medical treatment, mostly from minor injuries caused by flying glass. One woman suffered a broken back, and dozens of residents had temporary eye damage from the brighter-than-the-Sun flash. Hundreds of meteorites were recovered; the largest, at 1,442 pounds (654 kg), plunged into an ice-covered lake at hundreds of miles per hour. Again, though, no one was killed.

If the asteroid had been a little bigger or exploded more directly above the city, the damage to both structures and people could have been far worse. And if the asteroid had been large enough to hit the city, the results could have been catastrophic. "If it lines up over a city, even a fairly small object could injure or kill a lot of people," says Boslough.


KOEBAC/WIKIPEDIA


DENIS PANTELEEV

Fragments of the Pultusk meteorite (left) and the Chelyabinsk airburst

And we know that much larger asteroids have hit Earth in the past, gouging impact craters and killing every living thing across wide areas, and even extinguishing entire species.

Just ask the dinosaurs.

The beginning of the end for the dinosaurs came on a pleasant spring day 66 million years ago, when an asteroid as big as a mountain slammed into the Gulf of Mexico near the coast of the Yucatan Peninsula, with the equivalent of 100,000 gigatons of TNT—thousands of times the estimated destructive power of all the world's nuclear weapons combined.

The impact gouged a crater roughly 110 miles wide and 12 miles deep (180 x 20 km), known as Chicxulub. It also created a fireball that extended hundreds of miles in every direction, energized towering waves that inundated much of Texas and Florida, created a tsunami that circled the entire world, and blasted trillions of

tons of rock, dust, and steam into the sky. The dust, along with smoke from wildfires that engulfed most of the world's forests, circled the globe, blacking out the Sun for months or years. Chemical compounds forged by the heat and shockwave created a powerful acid rain. That apocalypse eventually extinguished the dinosaurs and most other life on the planet.

Chicxulub is the largest known death-by-space-rock event, but not the only one. Geologists have discovered about 150 impact craters across the globe. A few are larger than Chicxulub, but most are smaller. Scientists also have mapped millions of craters on the Moon, suggesting that Earth has undergone a similar bombardment. Most of Earth's craters have been erased by wind, rain, and the motions of its crust, leaving few visible scars.

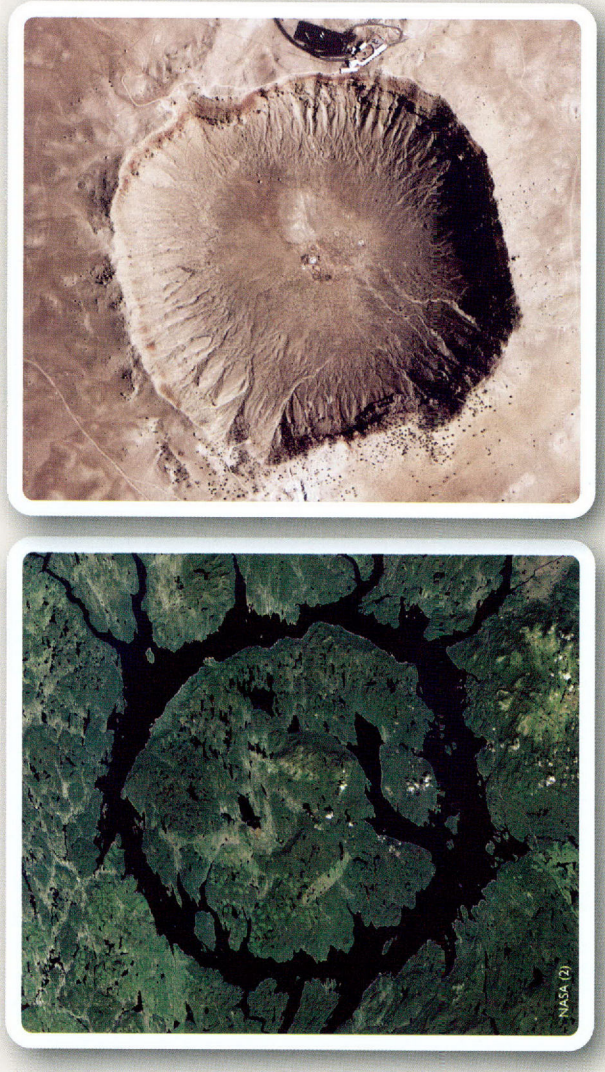
One of the freshest is Barringer Meteor Crater, a 4,000-foot (1.2-km) hole in the Arizona desert. It formed 50,000 years ago from the impact of an asteroid just 160 feet (50 meters) in diameter. The fireball and shockwave would have killed everything across thousands of square miles.

(The crater helped settle the debate over the origin of such structures on both Earth and the Moon. Early investigations suggested it was formed by volcanic processes, but later research proved its extraterrestrial origin.)

As a result of these and many other examples, scientists agree that space rocks can be killers. In fact, they estimate that your odds of dying from an asteroid strike—roughly one in 250,000, depending on which study you quote—are higher than dying from a lightning strike or shark attack. There's an important caveat, though: "Thousands of years might go by with nobody getting killed, then there's a big impact and hundreds of thousands get killed," says Boslough. That raises the overall probability that an individual could die from such an event.

And that leads us back to the basic question: How many people have been killed by space rocks? The possible answer ranges from zero to thousands.

During a military campaign in China on January 14, 616, "a large shooting star like a bushel fell onto the rebel Lu Ming-yeuh's camp," according to records of the Sui Dynasty. "It destroyed his wall-attacking tower and crushed to death 10 people." "Possibly, this is the earliest human meteorite casualty event in recorded history," according to a 1994 study on reports of death-by-meteorite in ancient China compiled by three NASA researchers from new translations of Chinese records.



Geologists have logged more than 150 impact craters on Earth, including Barringer Meteor Crater (top) in Arizona and 40-mile-wide Manicouagan, outlined by a deep lake, in Canada.

Although the reports could be in error, the study's authors note that Chinese royal courts kept detailed and accurate records on just about everything, including the heavens. Today, in fact, astronomers use imperial Chinese records to study lunar and solar eclipses, exploding stars, and other phenomena, suggesting there is little reason to doubt reports of falling meteorites.

And the reports are numerous. They say that a 1341 meteorite storm in Yunnan province, for example, claimed many casualties (although there are no specific numbers). "The records seem to indicate a heavy fall of meteorites vividly described as 'iron rain,'" according to the study. "Also the descriptions that 'houses and hill tops were all with bore holes' are consistent with modern reports of an iron meteorite shower."

In February or March of 1490, meteorites in Ch'ing-yang province killed more than 10,000, according to one Ming Dynasty source, while another says "they struck dead several tens of thousands of people." The largest impacting fragments were compared to "goose's eggs," suggesting they weighed a few pounds—heavy enough to kill. The asteroid that created the possible shower would have been comparable to the one that exploded above Tunguska, the 1994 paper noted, and such events are predicted to occur once every few hundred years.

On the other hand, the authors were dubious of the casualty numbers, suggesting the reports could have described a particularly nasty hailstorm, while other meteorite experts have said they could have been military propaganda or the result of translation errors.

Regardless of the accuracy of the Chinese accounts, many scientists continue the quest to find evidence of deaths from the sky. In 2020, for example, a team from Turkey and the United States that was scouring recently digitized records from the Ottoman Empire found reports that two men were hit during a meteorite fall in 1888, killing one and paralyzing the other.

"We know it is true and we can trust those documents since almost every single event was recorded in the Ottoman Empire period and these are official documents, from the governors' declarations to the higher authorities ... and signed by them officially," says lead author Ozan Unsalan, a planetary scientist at Ege University in Turkey.

Several studies in the past few years have claimed that massive airbursts similar to the one at Tunguska have caused deaths or other serious problems.

The first says that the Younger Dryas, a global cooling event in the northern hemisphere roughly 13,000 years ago, probably was triggered when a large comet exploded in the atmosphere, spraying debris across a large area. Studies report finding layers of ash that could have been deposited by widespread fires, elements with a likely extraterrestrial origin, microscopic diamonds formed during a high-pressure event, and other evidence. Proponents argue the event could have caused large-scale die-offs of life in North America and led to the demise of some of the continent's early human cultures.

Other studies have reported evidence of an airburst 3,700 years ago above Tell el-Hammam, a city in present-day Jordan. Scientists involved in the study say the explosion wiped out hundreds of square miles north of the Dead Sea, destroying all the nearby cities and towns. They've found evidence that the region was instantly heated to temperatures hotter than the surface of the Sun, along with layers of ash deposited at the same time. In addition, they report that surviving ruins were all slumped in the same direction, indicating they were knocked over by something powerful.

Earlier this year researchers reported similar evidence for an airburst over the Ohio River Valley in the United States between the years 252 and 383. According to their study, the blast affected more than 5,000 square miles (15,000 square km) and eventually led to the collapse of the Hopewell Culture, which formed a vast civilization across the Midwest. The team even found evidence of burned villages, although "it's not the idea that the air burst killed everybody," lead author Kenneth Tankersley told the *Washington Post*. "But rather that it was a catastrophic event" that caused the culture to break down.

Boslough and others disagree with the finding from all three studies, in part because they say the dynamics of airbursts don't fit the studies' simulations and because the populations of NEOs don't match the rate needed to support so many encounters.

"We can count the objects in NEO surveys and infer how many there must be," says Boslough. "We also know the rate of discovery. From that, we can infer how many of each size there are in Earth-crossing orbits. We understand orbital mechanics, so we know there couldn't have been a whole lot more in the recent past that just disappeared. If there were, we should see a lot more craters."

The three events, along with several others reported by other groups, probably will need additional physical evidence—from impact craters to age-dated meteorites—to gain wider acceptance.

That leaves Tunguska as perhaps the most widely accepted killer rock (or iceball) from space. A 2019 study reported evidence of at least three victims of the blast, as recorded by a Soviet scientist during a meeting with the Evenki in 1926.

"Inside the tree fall line, conditions were quite perilous," the study reported. "Many, if not all, people in the area fell unconscious for hours or days. In some cases, falling unconscious coincided with the arrival of the airburst, suggesting some form of concussion was responsible. Others may have fallen unconscious because of smoke inhalation, with combustible materials burning nearby, or fainted from shock."

A woman named Akulina reported that the shockwave threw her husband, Ivan, roughly 130 feet (40 meters), into a tree. "His arm had been broken by the tree trunk, a bone protruding through his bloodied shirt. At this sight, I fainted and fell down," she said. She soon recovered but was unable to provide much help. "Poor Ivan howled like a wolf, cried, swore, and shouted that he was in pain. ... Ivan ate very little; he moaned all over, complained of severe pain in the broken arm and finally fell asleep."

Another Evenki reported that his family's hut was destroyed by strong winds, which were accompanied by smoke, a flash in the sky, and the sound of thunder. "I told my father everything I saw," the man reported, according to a new translation by the authors of the 2019 study. "'I saw it,' my father shouted in fear. He began to cry out, began to swing and move uncontrollably... . The old man sang with his eyes closed, he rose to his feet, but then sat down at the fireplace as he could not stand up. Then he lay down on his bed and immediately died, completely dead."

The study says more casualties were related in 1934 by another Evenki woman, who was living in an encampment of eight huts, known as chums, when the blast occurred. "We were still asleep, as a storm and thunder came to us. The trees fell, the chum flew away, and winds lifted the people with beds and all from the ground many times over. I was unconscious until evening. Some died even... My man also died."

There are hints that even more people died in regions near the center of the blast. Those haven't been confirmed, though, and even those in the study aren't accepted by all researchers. Still, they provide some of the best evidence yet that people have been killed by extraterrestrial visitors.

Resources

Books

Rain of Iron and Ice: The Very Real Threat of Comet and Asteroid Bombardment, by John S. Lewis, 1996

Tunguska: A Siberian Mystery and Its Environmental Legacy, by Andy Bruno, 2022

Chelyabinsk Superbolide, Nick Gorkavyi et. al, editors, 2019

T.rex and the Crater of Doom, by Walter Alvarez, 2008

Impact: How Rocks From Space Led to Life, Culture and Donkey Kong, by Greg Brenneka, 2022

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What Is Known (and Not Known) About the Tunguska Event
www.britannica.com/story/what-is-known-and-not-known-about-the-tunguska-event

Damond Benningfield is executive editor of StarDate *and writer/producer of StarDate radio.*

by Alan MacRobert

Magnificent Mars Takes Center Stage

Mars shines at its most brilliant in November and December as it reaches opposition, shining through all or most of the night. Jupiter remains in great view, while Saturn begins its exit from the evening sky. On the other hand, Venus and Mercury climb into view in the evening sky of December. The stars of winter begin to replace those of autumn in December, with magnificent Orion climbing across the south, trailed by Sirius, the brightest star in the night sky.

NOVEMBER 1-15

Jupiter and Saturn dominate the southeast and south, respectively, during dusk and after dark. Jupiter is the brightest dot in the sky now, at magnitude minus-2.8. Saturn is no competition for it at magnitude 0.8, a thirtieth as bright. Even so, Saturn stands out as the brightest point in its dim, subdued sky area of Capricornus and Aquarius. In late twilight, find Saturn to Jupiter's right by about four fists at arm's length. Later in the evening, Saturn moves to Jupiter's lower right. It sets around midnight or 1 a.m.

Mars rises ever earlier in the night, and shines ever brighter, as it approaches its opposition a month from now. Look for Mars coming up over your northeastern horizon roughly a half hour after full dark: about 9 p.m., depending on your location, then 8 p.m. after we switch to Standard Time on November 6.

Mars glares yellow-orange. It's currently as brilliant as Sirius, the brightest star in the night sky, at magnitude minus-1.4, and second only to Jupiter. It reaches its highest and telescopic best in the south around 2 or 3 a.m. In the first half of November, Mars widens from 15 to 16.5 arcseconds, which is bigger than we've seen it in a couple of years.

Mars shines in eastern Taurus. It's passing between the bull's horntip stars, Beta and Zeta Tauri, above it and below it, respectively. Mars lies exactly on the line between them on the night of November 13.

The Moon accompanies Saturn on November 1, Jupiter on the 4th, and Mars on the 10th and 11th.

Look toward the northeast these evenings, a couple of fists to Mars's upper left, and there's pale yellow Capella slowly gaining altitude. Shining at magnitude zero, it's one of the brightest stars of any season.

Above Capella is a large star scattering that forms the constellation Perseus, hero of Greek myth. To the upper left of Perseus, look for the W-shaped pattern of five stars marking Cassiopeia. The W stands on end in early evening. Later, the W starts to tip over to the left.

Vega, a match for Capella, shines half-way up in the sky in the west to northwest. And lower in the south is the lonely Autumn Star, Fomalhaut.

Meteor Watch

The Shower	The Shower
Leonids	Geminids
Named for the constellation Leo, the lion, which rises in the wee hours of the morning. Its most prominent star, Regulus, stands at the bottom of a pattern of stars that looks like a backward question mark.	Named for Gemini, the twins. This shower can produce some especially bright meteors, although its peak viewing time is shorter than that of many other showers. Expect a peak rate of 100 or more meteors per hour.
Peak	**Peak**
Night of November 16/17	Nights of December 12/13
Notes	**Notes**
The last-quarter Moon will be in the way for peak meteor-viewing hours.	The gibbous Moon will be in the way for peak meteor-viewing hours.

NOVEMBER 16-30

Mars comes up an hour earlier than it did two weeks ago, and by 11 p.m. it's a good 60 degrees high, in almost the steadiest air possible. In the second half of November, Mars grows from 16.6 to 17.2 arcseconds in apparent diameter—the biggest it will appear until 2033!

Jupiter and Saturn, meanwhile, have migrated westward. The two giants are now roughly the same height as soon as they become visible in the fading twilight. For the rest of the evening, their line tilts as Saturn sinks.

After dark, look high above Jupiter for the Great Square of Pegasus, which is tilted enough to look more like a diamond than a square. It's big enough that your fist fits inside it. If you're in the latitudes of the southern U.S., the square passes almost straight overhead. It's formed by stars of merely moderate brightness.

Extending left from the Great Square's left corner when you face south is a big, long row of three second-magnitude stars (including the corner star). These are the backbone of the constellation Andromeda.

Now follow the western (right-hand) side of the Great Square down toward the south by three and a half times its own length. This brings you to first-magnitude Fomalhaut, the only bright star of Piscis Austrinus, the southern fish.

Follow the southeastern (bottom left) side of the Great Square down to the south and you'll be near Diphda, or Beta Ceti, one of the few bright stars of enormous Cetus, the whale.

Draw a line through the Great Square from the bottom to top points of the diamond, then extend the line one and a half times its length. This brings you near Deneb. Farther on in about the same direction is brighter Vega.

DECEMBER 1-15

Mars takes center stage! The glaring orange planet, now magnitude –1.8, is closest to

Earth on December 1 and at opposition on the 8th, when it aligns opposite the Sun in our sky. Still in Taurus, Mars dominates the eastern evening sky. It far outshines Mars-colored Aldebaran, which is about a fist to its right.

And this Mars opposition comes with a dramatic coincidence. On the evening of December 7, the full Moon will occult (cover) Mars for skywatchers in most of North America. Only the southeastern U.S. and the East Coast will miss out. But even there you can watch the Moon skim just past Mars.

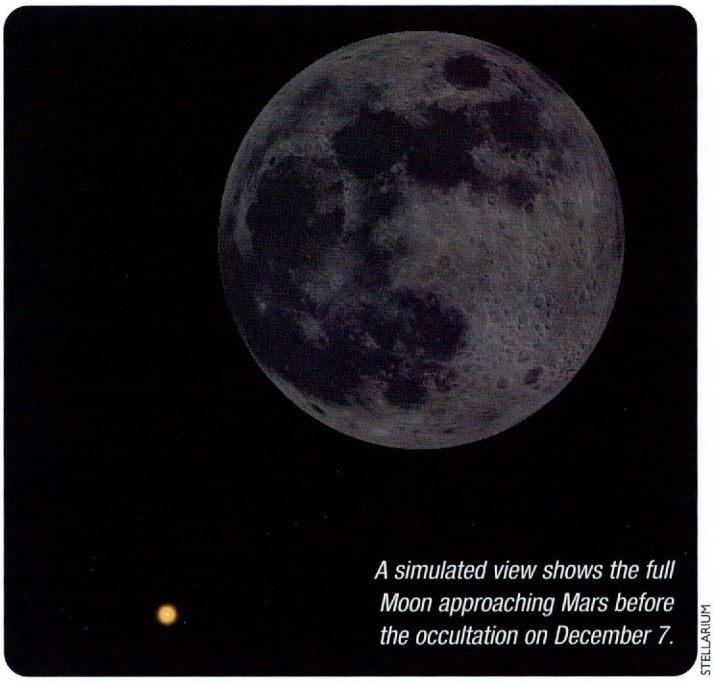
You will need a telescope to watch the occultation itself, because with the unaided eye or binoculars, the glare of the Moon's edge will hide the tiny planet when the edge creeps very close to it.

The "graze line," where the hilly limb of the Moon skims across the face of Mars but never covers it completely, runs from the New England coast through the central Midwest, eastern Texas, and northern Mexico. Observers north and west of this line get the complete occultation.

Timetables for many cities are at *http://lunar-occultations.com/iota/planets/1208mars.htm*. There you get three tables: for Mars's disappearance, reappearance, and the locations of cities. Scroll down to the "US" country codes to find your disappearance time, then again farther down for your reappearance time.

Jupiter, meanwhile, shines even brighter than Mars, high in the south in early evening, even as Mars commands the excitement. Saturn is much fainter and heading down, way over in the southwest.

While Jupiter and Saturn float amid the dim water-themed constellations of fall, Mars heralds the bright winter constellations about to come up in the east.



A simulated view shows the full Moon approaching Mars before the occultation on December 7.

STELLARIUM

To the upper left of Mars, spot bright Capella. To the upper right of Mars, by a little less, is the fingertip-at-arm's-length Pleiades cluster.

As evening advances, watch well to Mars's lower right for Orion to rise. By about 8 p.m., all of Orion is clear of the horizon. His three-star belt in his middle is roughly vertical.

Look off to Orion's left for Gemini and its bright "twin" stars, Castor and Pollux, at the left end of the constellation. Castor stands above Pollux, which is the brighter of the two.

DECEMBER 16-31

Mars has begun its long, slow shrink and fade, but it reaches a convenient observing height ever earlier in the evening now. The planet still glares in Taurus, keeping company with its modest imitator, Aldebaran.

Orion now clears the east-southeastern horizon soon after nightfall. Follow the direction of Orion's Belt down to the horizon. That's where brilliant Sirius, two fists below the belt, will rise around 8 o'clock (depending on your location and the date).

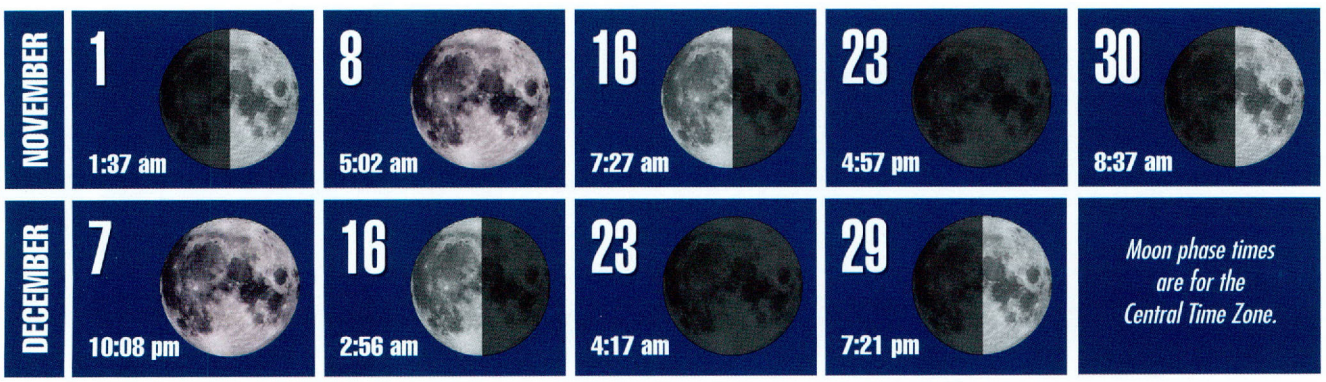
Sirius twinkles surprisingly slowly and deeply when it's barely above the horizon. Its shimmering speeds up as it gains a bit of altitude. All stars do this, but Sirius is bright enough for the effect to be obvious; when stars are very low they're greatly dimmed by the atmosphere.

Sirius is the Dog Star. Off to its left or upper left is Procyon, the Little Dog Star. Sirius and Procyon team up with Betelgeuse, Orion's reddish shoulder, to form the Winter Triangle. It will be at its highest in late evening when winter is coldest, in late January.

The final two naked-eye planets, Mercury and Venus, now emerge after sunset near the southwestern horizon. Keep watch there starting 20 or 25 minutes after sundown. Binoculars will help.

You'll probably see Venus first; it's much brighter than Mercury, though lower. Once you've got Venus, seek Mercury a little to its upper left. The gap between them shrinks from six degrees on December 15 (three or four finger-widths at arm's length) to just 1.5 degrees on the 28th and 29th. That's when the two planets will be in conjunction, with Mercury passing to Venus's upper right.

Alan MacRobert is a senior editor of Sky & Telescope *magazine.*



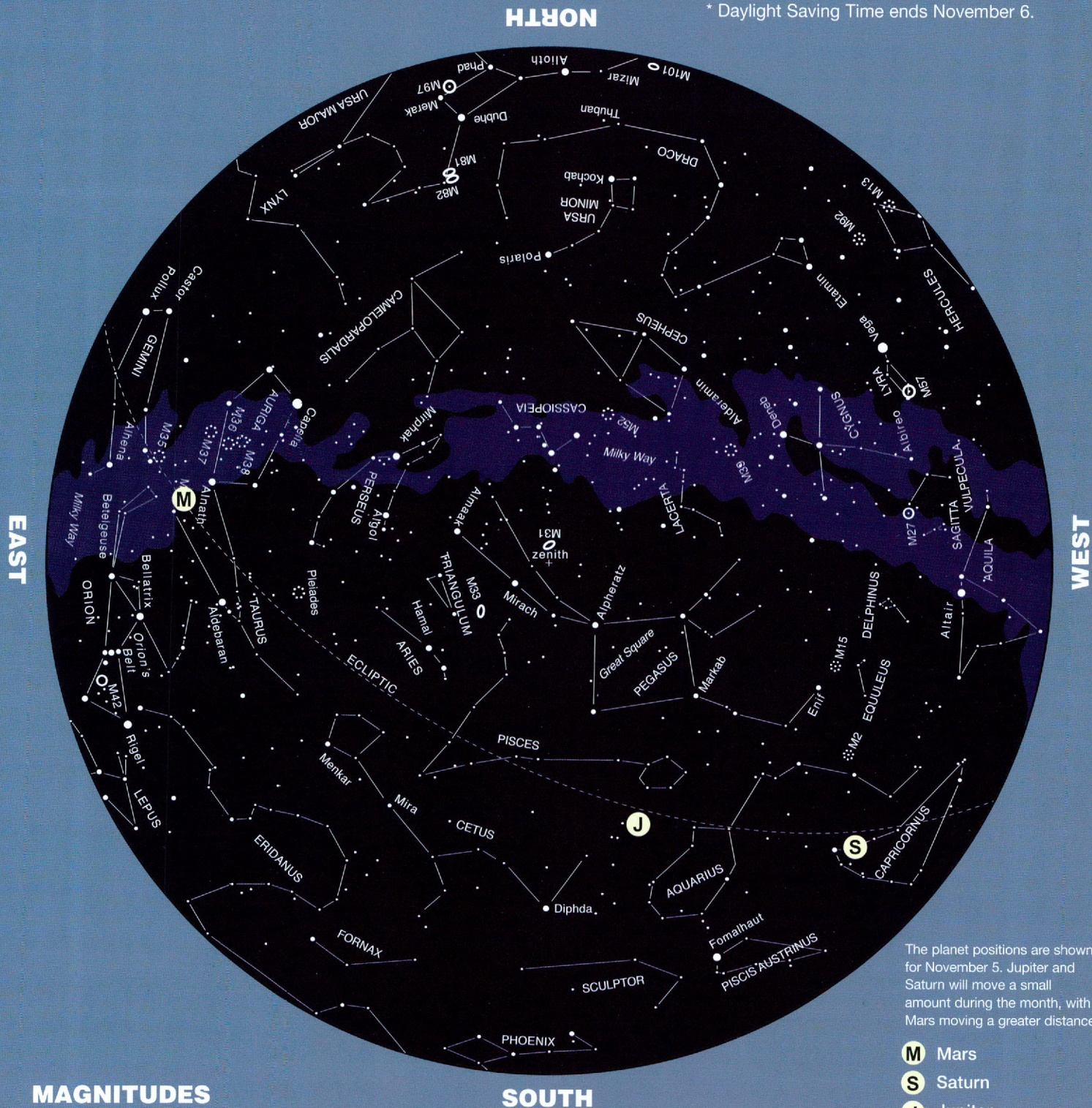
NOVEMBER

How to use these charts:

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

October 20	**Midnight**
November 5	**11 p.m.**
November 20	**9 p.m.***

* Daylight Saving Time ends November 6.



MAGNITUDES

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

The planet positions are shown for November 5. Jupiter and Saturn will move a small amount during the month, with Mars moving a greater distance.

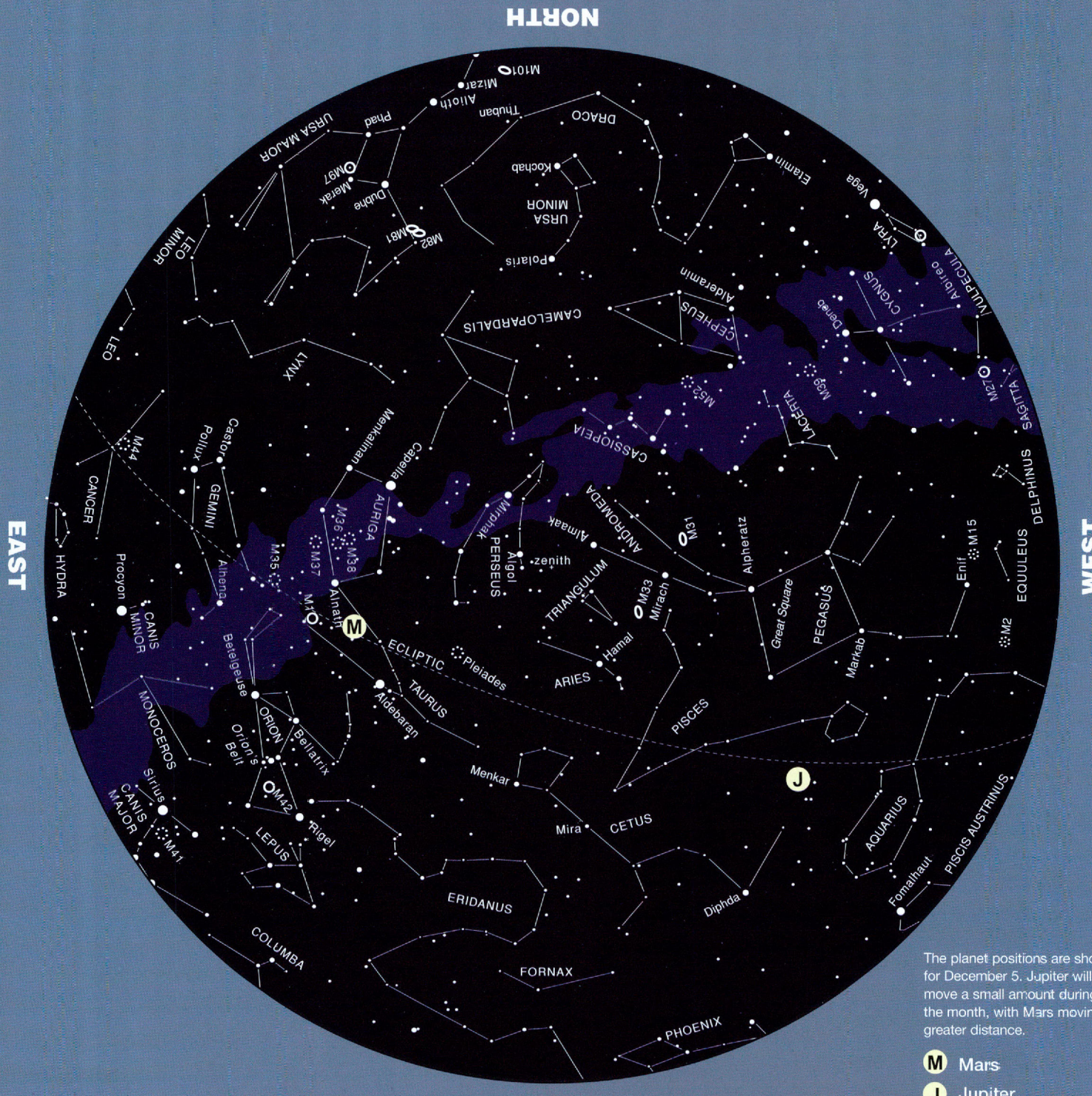
- M Mars
- S Saturn
- J Jupiter
- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

DECEMBER

How to use these charts:

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

November 20	**11 p.m.**
December 5	**10 p.m.**
December 20	**9 p.m.**



MAGNITUDES

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The planet positions are shown for December 5. Jupiter will move a small amount during the month, with Mars moving a greater distance.

- Mars
- Jupiter
- open cluster
- globular cluster
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- galaxy

Holding the Universe (or Pieces of it) in Your Hands

In the year 1006, the light from an exploding star reached Earth. The star was a white dwarf—the corpse of a once Sun-like star. It pulled gas from the surface of a companion star. So much of the gas piled up on the white dwarf that it exploded as a supernova, ripping itself to bits.

Today, the remnants of the dead star form a giant bubble that is expanding into space at millions of miles per hour. Astronomers have studied it in many wavelengths, producing colorful images that look like the opening to a cave, or perhaps a Yellowstone-like pool of mineral-rich water.

The images don't tell the full story of how the supernova remnant is evolving, though. To expand the story, astronomers have turned to the third dimension, creating and printing 3D models that look like caramel-coated popcorn balls. That tells astronomers not just about the supernova, but about the clouds of gas and dust it's encountering as it expands.

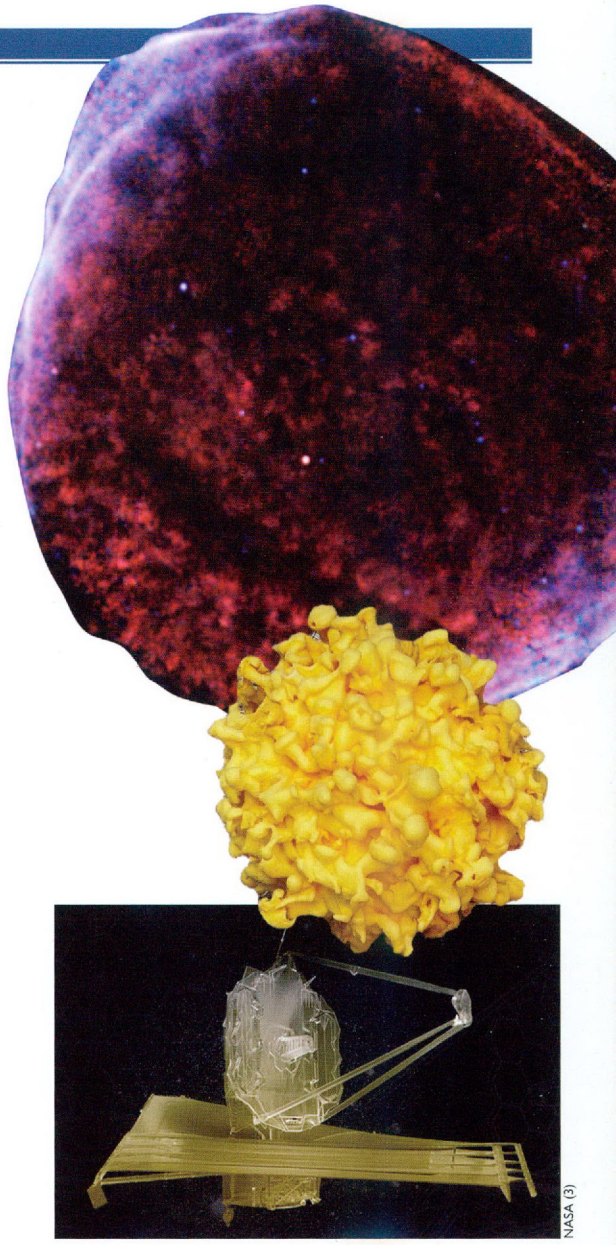
That's one of many examples of how 3D-printed models are revealing new details about the universe, according to Kimberly Arcand and Megan Watzke, authors of *Stars in Your Hand: A Guide to 3D Printing the Cosmos*. "Astronomers have begun to take the vast reservoirs of data available to them and search for ways to go beyond a flattened view of space," they write. "Like learning a hidden language that was unknown to them previously, astronomers are now deciphering the code found in these data that reveal the three-dimensionality of space."

But it's not the only use for 3D printing and models in the space business. NASA and space companies are using the technology to make parts for rockets and spacecraft, and tools for astronauts on the International Space Station.

NASA are others are sharing many of their models, allowing the rest of us to use our own 3D printers to create accurate representations of supernova remnants, the large-scale structure of the universe, the surfaces of Mars and the Moon, the rockets and spacecraft that captured many of these views, and much more.

Stars in Your Hand offers scores of examples while a companion web site provides links to ready-to-print files, including 3D models of the constellations, which allow the visually impaired to experience the outlines of the classic star patterns. Space hardware includes Hubble and James Webb space telescopes, the Apollo lunar lander and Moon rocket, and the Kepler space telescope, which discovered more than 4,000 planets in other star systems.

Finally, the book includes examples of interesting objects in the universe, from Hubble's famous "Pillars of Creation" to spiral galaxies to busy star clusters. These models allow us to see the universe as astronomers often do: from all angles.

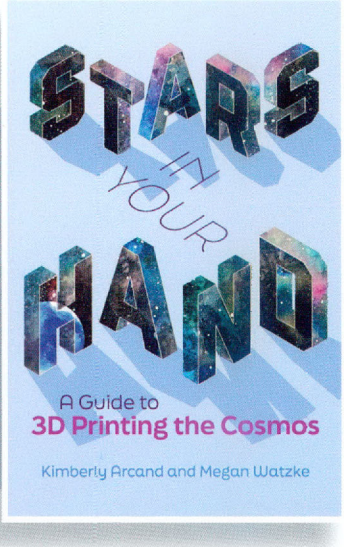


NASA (3)

From top: a false-color two-dimensional image of the Supernova 1006 remnant, with a 3D model beside it; a printed model of James Webb Space Telescope

Stars in Your Hand
A Guide to 3D Printing the Cosmos
By Kimberly Arcand and Megan Watzke
Paperback, $21.95
starsinyourhand.pubpub.org

Additional 3D model source
nasa3d.arc.nasa.gov/models/printable



It's eclipse season!

Lunar, solar eclipses are part of the same cycle

After a partial solar eclipse in October, Earth, Moon, and Sun will come into alignment again on the night of November 7 to produce a total lunar eclipse, at least part of which will be visible across the entire United States.

It's not a coincidence that the eclipses take place two weeks apart. In fact, eclipses always come in pairs—unless they come in threes—and always two weeks apart.

That's because eclipses require precise alignments of Earth, Sun, and Moon. Solar eclipses, for example, occur when the Moon passes directly between Sun and Earth, allowing the Moon's narrow shadow to track across Earth's surface. Lunar eclipses occur when the Moon aligns exactly opposite the Sun, so the Moon passes through Earth's wider shadow.

However, the Moon's orbit around Earth is tilted slightly with respect to the ecliptic, which is the Sun's path across the sky. So most months the new and full Moon pass above or below the ecliptic, so there are no eclipses.

When the Moon crosses the ecliptic at just the right time, though, it brings Moon, Earth, and Sun into alignment. In fact, it happens twice, separated by about two weeks—once when the Moon crosses the ecliptic from north to south (or vice versa), then again when it crosses in the opposite direction. Combined, they create an eclipse season. When the Moon is between Earth and Sun the alignment creates a solar eclipse, and when the Moon is on the opposite side of Earth it creates a lunar eclipse. They can happen in either order, and the cycle repeats roughly six months later.

The total length of an eclipse season is five weeks, so if there's an eclipse early in that period, there can be a third eclipse at its end—usually two poor eclipses flanking one good one. And if the year's first eclipse season begins in early January, there can be three seasons during the year, producing as many as seven eclipses—which will happen in 2038.

The eclipse of November 7/8 is the second and final event of the current season. It starts shortly after 3 a.m. Central Time on the 8th, when the edge of the Moon first touches Earth's dark inner shadow. That begins a partial eclipse, with the Moon partially in shadow and partially in sunlight. The total eclipse begins about an hour later and lasts for 85 minutes.

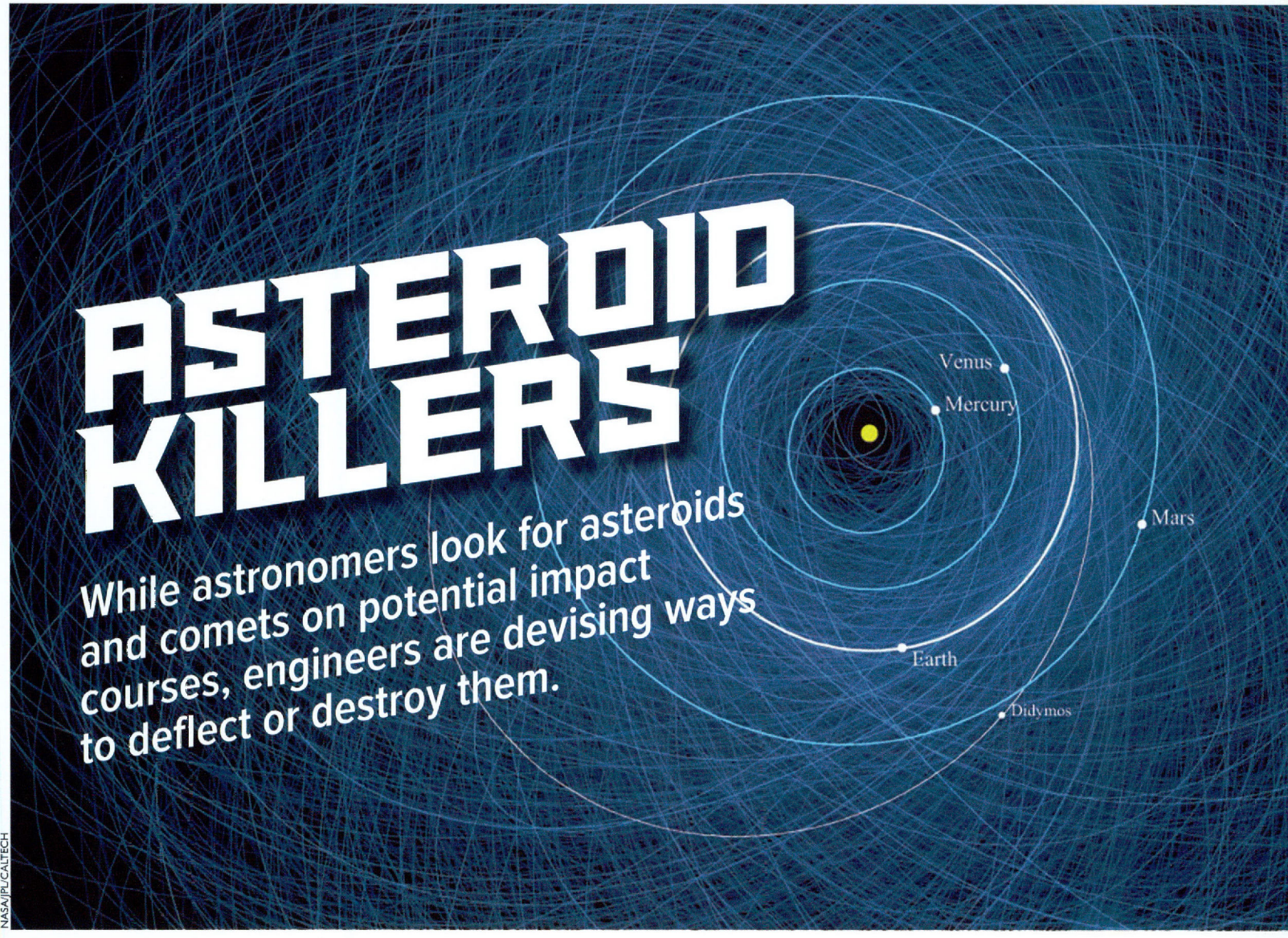
Skywatchers west of a line from South Texas to Lake Superior, including all of Alaska and Hawaii, will see the entire total eclipse and most of the partial. Most of those to the east of that line will see all of the total eclipse, but the Moon will set during the partial phase.

TIME	ECLIPSE EVENT
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, November 8	

NASA/RAMI DAUD

The full Moon is fully illuminated by sunshine (left), then loses bigger 'bites' to Earth's shadow before being fully eclipsed (right). Sunlight filtering through Earth's atmosphere colors the Moon dark orange.

ASTEROID KILLERS



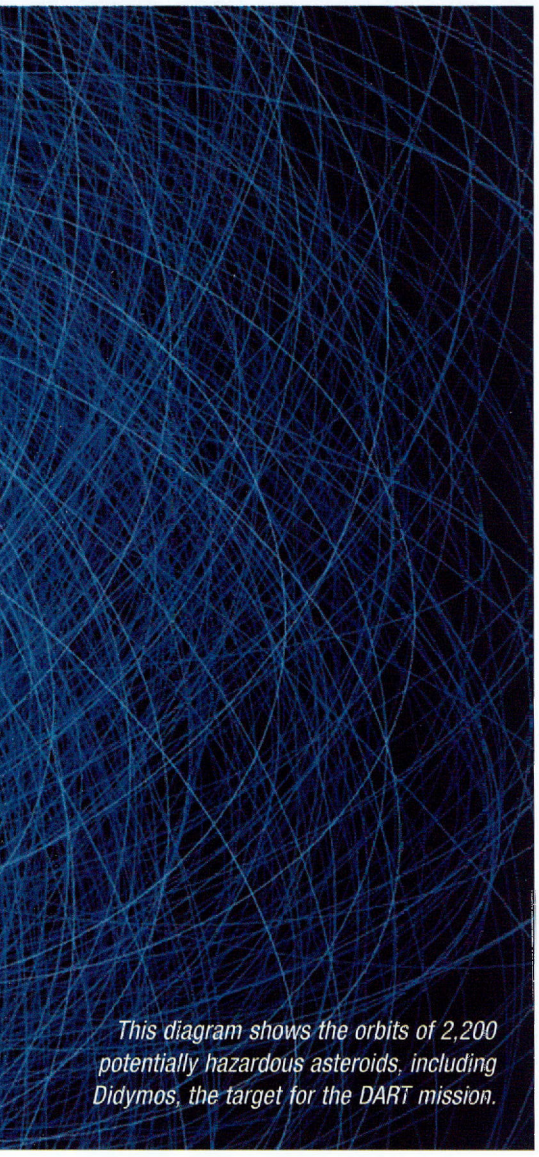
NASA/JPL/CALTECH

While astronomers look for asteroids and comets on potential impact courses, engineers are devising ways to deflect or destroy them.

Each night, astronomers around the world diligently look for killers: asteroids or comets that are big enough to devastate cities, states, or even the entire planet. They've discovered and plotted the orbits of most of the possible planet killers, so they can predict the locations of these big chunks of rock and ice decades into the future. But they've logged less than half of the potential city killers, leaving Earth vulnerable to attacks, so they continue to scan the skies.

Scientists and engineers also are pondering ways to defend our planet if the searches uncover a deadly object on a potential collision course. The possibilities range from painting the object's surface, to zapping it with a laser or a fusillade of small projectiles, to nuking it. None of the techniques has been proven, and only one has been tested—and we might not know its results for months. Still, they could offer a fighting chance to protect Planet Earth from its hostile environment.

BY JASMIN FOX-SKELLY



This diagram shows the orbits of 2,200 potentially hazardous asteroids, including Didymos, the target for the DART mission.

You might think that finding asteroids among the millions of stars in the sky is rather like looking for a needle in a haystack, but scientists already track about 90 percent of asteroids that are at least one kilometer (0.6 mile) in diameter using Earth-based telescopes with extremely wide fields of view.

The telescopes continually scan the sky looking for unusual movement. Cameras take a series of photos of the same region of sky separated by several minutes or hours, and sophisticated software scans the images to see if any objects have moved against the background of stars during that time. Anything that's moving at an especially fast pace could be especially close to Earth.

On a typical night, these searches reveal thousands of previously unseen asteroids, almost all of them in the asteroid belt, between the orbits of Mars and Jupiter. (The searches have boosted the known asteroid population from just 5,000 in 1987 to more than 1.2 million today.)

To calculate the orbit of an asteroid, astronomers measure its position and brightness in each of the images. "It's like a dot-to-dot puzzle a child might do to reveal a picture," says Eric J. Christensen, director of the University of Arizona's Catalina Sky Survey, only a lot more complicated: "You have to keep searching for more dots, and then account for the motion of both the object and observer through space and time, gravitational and non-gravitational perturbations, variable amounts of uncertainty in the measurements, and even the time it takes light to travel from the asteroid to our telescopes."

If any of the surveys detect an object larger than 140 meters (about 460 feet, which is big enough to devastate or destroy a city), details are forwarded to the Minor Planet Center in Cambridge, Massachusetts. It collects observations of asteroids, comets, and other small bodies in the solar system; plots their orbits; and maintains a repository of the data for scientists around the world.

Any object of concern also is reviewed by scientists at the Center for Near Earth Object Studies at NASA's Jet Propulsion Laboratory in California, who calculate the orbits of Near-Earth Objects (NEOs) and the probability that any will slam into our planet over the next century. (An NEO is any comet or asteroid that could pass within a few million miles of Earth.)

Currently, the center is tracking about 30,000 NEOs. Of these, more than 2,200 are classified as potentially hazardous, because their orbits overlap Earth's, providing opportunities for collisions.

Asteroids the size of a small mountain or bigger are easy to see, but smaller ones are more challenging. Yet asteroids as small as a few hundred feet in diameter could still do a lot of damage, and so far, astronomers say they're tracking only about 40 percent of them. "We're limited by the size of our instruments, by weather, by the usual day-night cycles," says Christensen. "We can only observe part of the sky, and only during nighttime hours with clear weather."

To help overcome some of these restrictions, NASA plans to launch an asteroid-hunting infrared space telescope in 2026. NEO Surveyor will hunt for good-sized asteroids that come within 30 million miles (50 million km) of Earth's orbit. Warmed by the Sun, an asteroid emits infrared energy, making it appear brighter (and, therefore, easier to detect)

NASA/JPL/CALTECH/JPL

Two asteroids appear as a series of orange dots in this image from a spacecraft. Asteroids move quickly against the background of stars, so a sequence of images reveals their presence.

than it does at visible wavelengths. NEO Surveyor should not only find such asteroids, but it should create dossiers on each one, with details on size, rotation rate, composition, and more—critical bits of knowledge for deciding how to deal with an asteroid.

Of course, finding potential impactors is only the first step. Once we know where they are, we'll need a way to intercept and destroy them—or at least deflect them enough to miss Earth. Possible strategies range from "kinder, gentler" to "blast them to cosmic dust."

If an approaching asteroid is detected early enough, it might be possible to divert it using a concept known as a gravitational tractor.

A spacecraft would fly alongside the asteroid for years to decades. The craft's slight gravitational pull might be enough to tug the asteroid away from its collision course. The tractor likely would work on an asteroid of any shape or composition, from a loosely bound rubble pile to a chunk of solid metal. It would work only on relatively small bodies, though, and would require many years to get the job done, which means we would need to know the asteroid's precise trajectory a long time in advance.

Another low-stress strategy involves painting parts of an asteroid's surface to alter its speed and direction. An asteroid absorbs sunlight, heating its surface. As the warm surface rotates into darkness, it emits some of its heat as infrared radiation, which imparts a tiny thrust, changing the asteroid's orbit. "Spray painting an asteroid with a metallic coating would change the amount of sunlight the asteroid [emits], creating a tiny amount of thrust, which would eventually divert it off its course," says Jonathan Katz, a physicist at Washington University in St. Louis.

In a recent study, Katz estimated that a small container of metallic paint should be enough to coat an asteroid a third of a mile (500 meters) across. Using this approach, Katz says that a 160-foot (50-meter) asteroid could be deflected by about 2,000 miles (3,000 kilometers) within a century, or about 620 miles (1,000 kilometers) in 30 years. Such an approach would require detailed information about the target asteroid along with a highly precise prediction of its impact site.

Other ideas call for more violent interventions. One, for example, would ram a spacecraft into an approaching asteroid, changing its trajectory enough to miss Earth.


NASA/JHUAPL

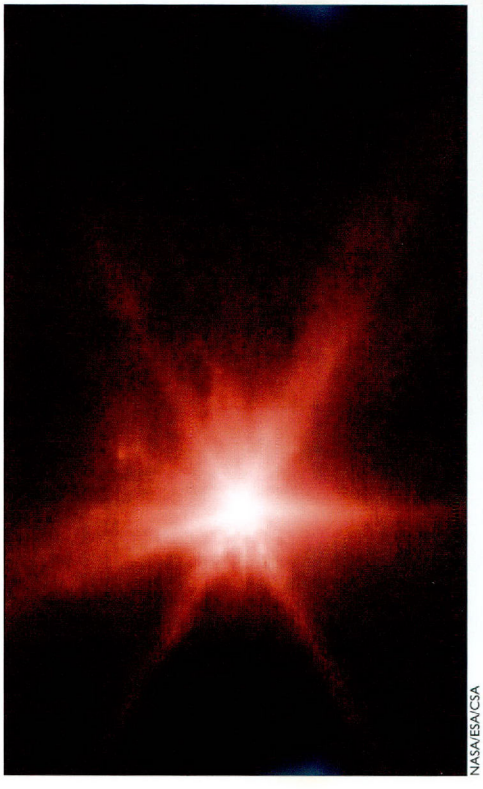
NASA recently tried that approach with the Double Asteroid Redirection Test (DART). The craft collided with Dimorphos, a 500-foot (160-meter) satellite of the asteroid Didymos, on September 26.

"I first came up with the idea behind DART in 2011, when I was in my basement doing morning stretches and exercises," says Andy Cheng, chief scientist for planetary defense at the Johns Hopkins Applied Physics Laboratory in Maryland. "The idea just came to me. We were already aware of Didymos, and we knew it was going to come very close to Earth in 2022, and so I thought ... we should have a mission and go out to Dimorphos and hit it with a spacecraft and then measure the orbit change using ground-based telescopes."

Astronomers will monitor the system for months, carefully tracking Dimorphos's orbit. By comparing the orbit before and after the impact, they should be able to tell exactly how successful DART was at altering the smaller asteroid's orbit, which should tell us whether it would be possible to deflect an asteroid on a collision course with Earth.

And, depending on the size and composition of the threatening asteroid, such an approach might work with a warning time of as little as a few years.

"There are always large spacecraft in production," says Cheng. "What you would do is hijack a spacecraft and launch vehicle, put in a different guidance system, a camera, a sensor, basically give it the abilities of DART and fly it to the asteroid. If that kind of emergency happened, there would be the will and the money to do that quite quickly."


NASA/ESA/CSA

But what if we don't have years of warning time? It's a scenario that's chillingly plausible.

In March 2020, for example, astronomers discovered a three-mile-wide comet, later named NEOWISE, traveling toward Earth from the direction of the Sun. It passed closest to Earth just four months later. Although its closest approach was 64 million miles, the event highlighted the fact that large objects can get through the warning net.

"People often say we know where all the large asteroids are but that's not true—we know where certain classes of things that are large are," says Philip Lubin, professor of astrophysics and cosmology at the University of California, Santa Barbara. "We didn't know where NEOWISE was and that was big. We only had a four-month warning and that was a five-kilometer-diameter comet,

Opposite page, from top: DART's final full image of Dimorphos, from a range of seven miles; a James Webb Space Telescope view of the asteroid system four hours after impact shows debris radiating into space. This page: Astronauts may someday help deflect threatening asteroids.

which is kind of close to the range you would consider as a planet killer, which means extensive loss of species, including humanity."

Lubin is developing a system caled Pulverize It, which would use explosive rods to penetrate deep into an asteroid, ripping it to shreds. The surviving chunks—perhaps no bigger than a house—then would enter the atmosphere, which would act like a bullet-proof vest, absorbing much of the impact energy.

"The basic idea is to take advantage of the fact that Earth has a very thick atmosphere, and that atmosphere is very difficult to get through at high speed," says Lubin. "By breaking the asteroid into small chunks, you are effectively spreading them out over a significant spatial area rather than hitting the Earth with one solid object. It would be like being hit by a bunch of little balls as opposed to a grand piano."

The system should be able to intercept and disarm asteroids in a matter of days or weeks. For example, Lubin and his team calculate that a football-field-sized target could be destroyed as little as five hours prior to impact, while something around the size of the Empire State Building could be dealt with just 10 days prior to striking Earth.

These aren't the only possible strategies. Some scientists have proposed deflecting an asteroid with lasers, or even hitting it with a nuclear missile. Unfortunately, aside from DART, all the concepts have a significant drawback: They are untested.

"You wouldn't feel comfortable driving a car no one had tested to make sure it wasn't going to explode or kill you, and no one in their right mind would implement a national defense system without testing it," says Lubin. "The minus side to almost every technique is that they require assumptions about what the fundamental interactions are between the asteroid and whatever is intercepting it. You need to know how your weapon will interact with the object, but the problem is that asteroids come in all kinds of different sizes, and the composition and what's under the surface is often unknown."

Another problem is public apathy. While the likelihood of an asteroid the size of the one that killed the dinosaurs hitting us is extremely low, since the early 20th Century, several sizable rocks have crashed into us.

On June 30, 1908, an asteroid or comet exploded with the force of several nuclear weapons in the atmosphere above Siberia. Luckily it came down in a remote, almost unpopulated region. Nevertheless, the blast flattened an estimated 80 million trees over 500,000 acres.

Another asteroid exploded above far-eastern Russia in 1947, also in an unpopulated region, raining fragments across a wide area and gouging craters up to about 85 feet (26 meters) across.

And in 2013, an asteroid about the size of a six-story building exploded above the city of Chelyabinsk, also in Russia. The shockwave shattered glass and injured at least 1,200 people.

"If these events had been flipped, and a meteorite the size of the one that hit Tunguska had impacted a city like Chelyabinsk, then it would have been a major wakeup call, as it would have killed a lot of people," says Lubin. "A meteorite that size coming down on Moscow, London, or New York could potentially kill one million people and possibly more. People would demand that we do something about it."

Jasmin Fox-Skelly is a freelance writer in Cardiff, Wales.

Resources

Internet

NEO Surveyor
solarsystem.nasa.gov/missions/neo-surveyor/in-depth

Minor Planet Center
www.minorplanetcenter.net

DART
dart.jhuapl.edu

Didymos/Dimorphos
solarsystem.nasa.gov/asteroids-comets-and-meteors/asteroids/didymos/in-depth

Center for Near Earth Object Studies
cneos.jpl.nasa.gov

Pulverize It
www.news.ucsb.edu/2022/020591/pulverizing-planet-killer

NASA Planetary Defense
www.nasa.gov/planetarydefense/overview

by Damond Benningfield

A Star of Many Colors?

Ancient records suggest supergiant Betelgeuse changed hue more than a millennium ago

The appearance of the supergiant star Betelgeuse changed dramatically a few years ago. From November 2019 through February 2020 it dropped to just a third of its normal brightness. Since then, astronomers have concluded that a dark storm on Betelgeuse bigger than the Sun caused a monstrous eruption of gas. Some of the gas cooled and coalesced to form a cloud of dark dust, partially blocking Betelgeuse from view. The ejection also quelled a 400-day cycle of in-and-out pulsations that caused much smaller changes in the star's brightness.

A study released in September suggests that Betelgeuse's appearance could have changed even more dramatically more than a millennium ago. The star may have grown noticeably brighter while its color changed from pale yellow to today's intense orange.

Betelgeuse marks the shoulder of Orion the hunter. It's normally one of the 10 brightest star systems in the night sky. Astronomers are uncertain about the rest of its resume, however, in part because they're uncertain about its distance. The uncertainty means it's hard to pin down the star's true brightness, which in turn creates uncertainty in its mass, age, and future.

By looking at historical descriptions of Betelgeuse's appearance, however, a team led by German astronomer Ralph Neuhäuser reported it was able to narrow the numbers. According to the team's calculations, Betelgeuse is 14 times the mass of the Sun, 14 million years old, and will end its life as a supernova in about 1.5 million years.

Researchers found several reports from roughly 2,000 years ago suggesting that Betelgeuse was fainter and paler than it is today.

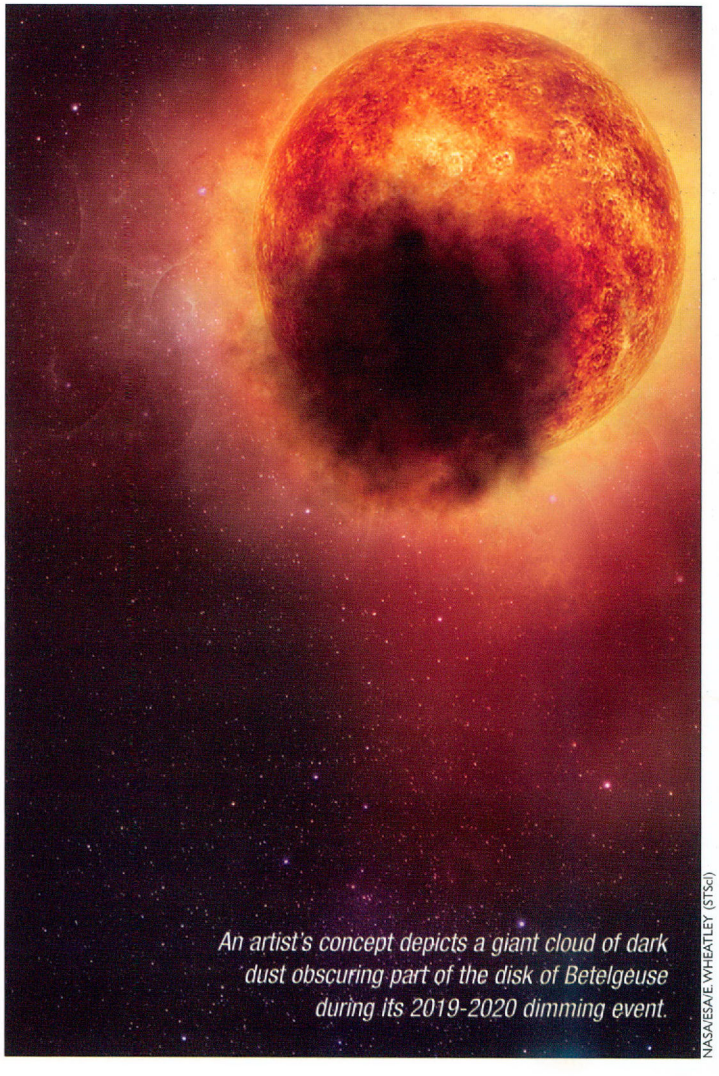
For example, Chinese astronomer Sima Qian compared Betelgeuse to the planet Saturn, which shines pale golden yellow. A century or so later, Roman astronomer Julius Gaius Hyginus made the same comparison. And later still, Greek astronomer Claudius Ptolemy didn't even mention Betelgeuse in a list of bright red stars. Records from other sources also hint that Betelgeuse looked different than it does today. By 1,000 years ago, however, every reliable source reported that Betelgeuse matched its current appearance.

(By comparison, all of the sources, both older and more recent, described the star Antares, another red supergiant, as bright red or orange like Mars, matching its current appearance.)

Using a distance estimate of about 500 light-years and models of how massive stars evolve, the team suggested that Betelgeuse underwent a major evolutionary jump between about 2,000 and 1,000 years ago. Its outer layers puffed up, making the star brighter and cooler, which in turn caused Betelgeuse to change color.

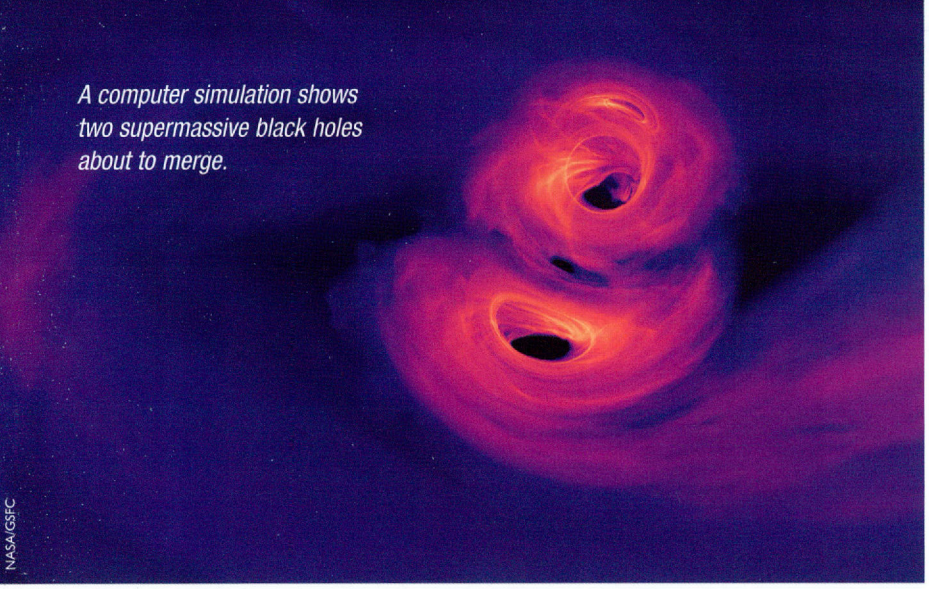
The research team said its results are consistent with other recent studies of Betelgeuse. One of those studies said the giant star might recently have swallowed a companion star, making it spin much faster. Another said that Betelgeuse was sent racing through space when a larger companion exploded as a supernova.

Although none of these findings, including the color change, have been confirmed by other scientists, they all suggest that Betelgeuse's appearance could have changed rapidly and dramatically over the millennia—and the changes may not be done yet.



An artist's concept depicts a giant cloud of dark dust obscuring part of the disk of Betelgeuse during its 2019-2020 dimming event.

NASA/ESA/E. WHEATLEY (STScI)



A computer simulation shows two supermassive black holes about to merge.

NASA/GSFC

An Unfriendly Merger

Giant black holes could come together in just three years

A pair of supermassive black holes in the heart of a distant galaxy may be headed for a collision in as little as three years, according to a recent study.

The black holes, which have a combined mass roughly 200 million times the mass of the Sun, are in the galaxy SDSS J1430+2303, which is about one billion light-years from Earth.

Observations by orbiting X-ray telescopes revealed that, over a couple of years, an oscillation in the brightness at the heart of the galaxy increased in frequency from once a year to once every three months. A team of researchers suggested the peaks in the cycle could be produced as the black holes approach each other, kicking blobs of hot gas away from the disks that encircle the black holes. The change in timing could mean that the black holes are drawing closer together, and could merge in just three years in a burst of X-rays and other forms of energy.

The merger also should produce an outburst of gravitational waves, which are ripples in space-time. No current detectors are sensitive to the wavelengths the merger should produce, so they will remain unobserved.

Zapped by the Sun

The Sun shot down 38 satellites in early February after launching two barrages of charged particles into space. A study released in August provides details on how that pulled the satellites to their doom.

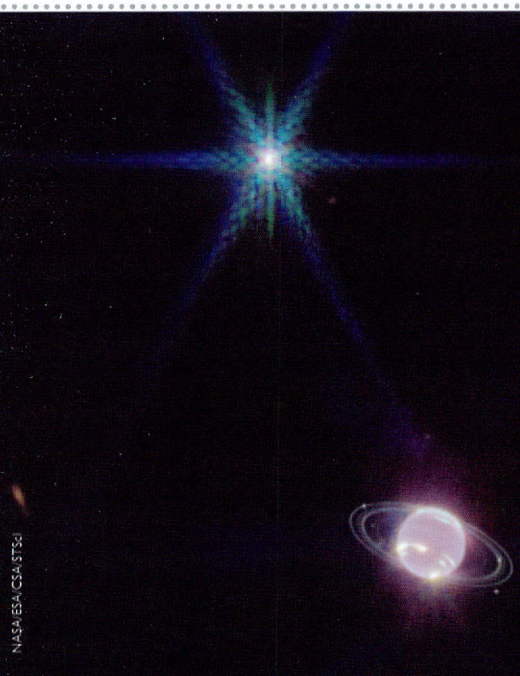
The satellites were part of the SpaceX Starlink constellation, which has deployed more than 3,000 craft to provide Internet access to poorly served regions of the globe. The company launched a cluster of 49 satellites on February 3, but 38 of them burned up in the atmosphere on February 4.

In a study published in August, scientists at the University of Science and Technology of China reported that the Sun produced a moderate flare and two eruptions in late January and early February, blasting giant clouds of charged particles into space. They swept past Earth at speeds of more than a million miles per hour on February 2-4.

The Starlink satellites were launched into orbits of 130 miles (210 km), with plans to increase their altitude to 340 miles (540 km) after a checkout period. Interactions with the storm clouds (known as space weather) increased the density of the atmosphere at the initial altitude by 21 percent, according to the study, increasing drag on the satellites and pulling them down.

"This event illustrates the complexity and difficulty of the space weather prediction, and also indicates that even small storms might induce severe astronautic and financial consequences," the study notes.

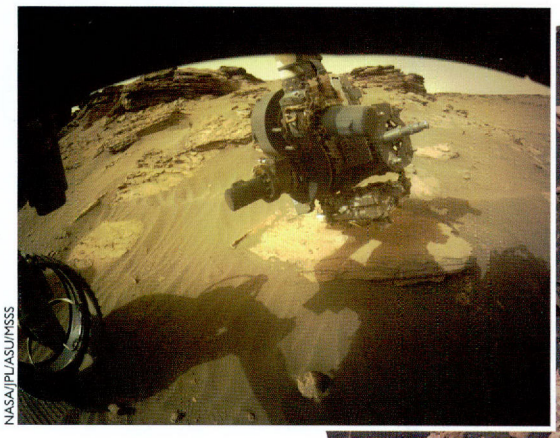
Subsequent Starlink launches have placed the satellites into 185-mile (300-km) initial orbits to reduce the risk of additional losses. The Sun is entering the active phase of its 11-year magnetic cycle, however, so all orbiting satellites face increased dangers from our star.



NASA/ESA/CSA/STScI

Peeking at a Distant Giant

Giant Neptune, its rings, and its largest moon, Triton, glimmer in this false-color image from James Webb Space Telescope. Neptune, the most remote of the Sun's eight major planets, looks dark in the picture because the image was compiled using several infrared wavelengths, which are invisible to the human eye. The dark areas are produced by methane in the upper atmosphere, while the brighter areas are high-altitude clouds. The infrared also provides especially good views of the rings, which are dark and hard to see at visible wavelengths. Triton, at upper left, appears much larger in comparison to Neptune in part because its surface is much richer in methane. Several other moons look like stars near Neptune, while a few galaxies are visible in the background.



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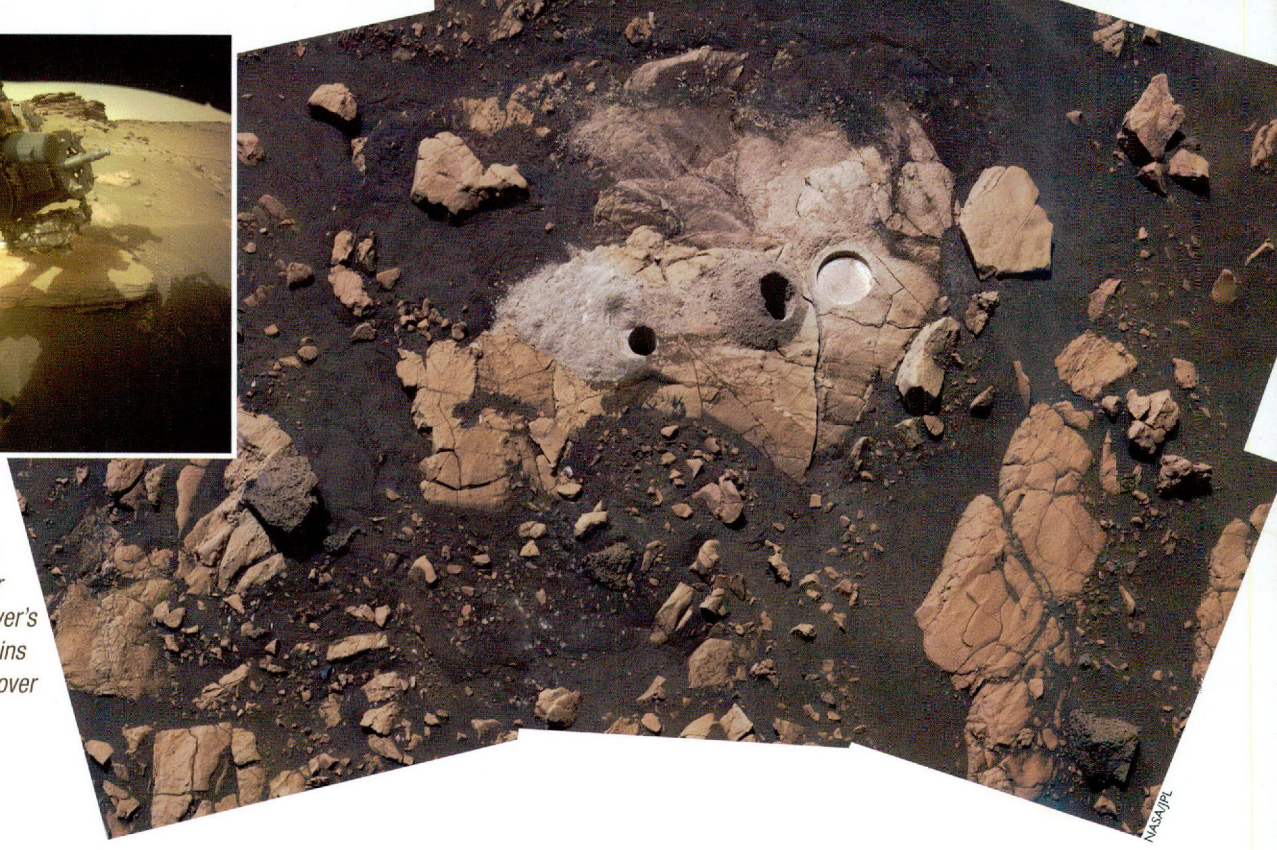

NASA/JPL

A close-up (right) shows three holes that Perseverance drilled into the rocks to analyze their composition. Top: The rover's robotic arm, which contains the drilling tools, hovers over another rock formation.

Mars Rover Finds Cozy Niche, Preps for Sample Return

Jezero Crater, the landing site of the Perseverance Mars rover, could have been a comfortable home for life about 3.5 billion years ago. The nuclear-powered rover discovered organic compounds—the chemical building blocks of life—in sediments in an ancient river delta. The rock layers in which the sediments were found indicate that environmental conditions would have been favorable for life.

"While the detection of this class of organics alone does not mean that life was definitively there, this set of observations does start to look like some things that we've seen here on Earth," said Sunanda Sharma, a mission scientist at the Jet Propulsion Laboratory, in a September press conference. "To put it simply, if this is a treasure hunt for potential signs of life on another planet, organic matter is a clue. And we're getting stronger and stronger clues as we're moving through our delta campaign."

Jezero is 28 miles (45 km) in diameter, and was filled with a deep lake in the distant past. Planetary scientists had expected it to be paved with sedimentary layers, which form as rocks and grit in the water settle to the bottom and cement together. Instead, the rover's chemical laboratory and ground-penetrating radar have found that most of the rock on the crater floor was formed in volcanic processes.

Sedimentary rocks do form the river delta, which was deposited when Mars was much warmer and wetter than it is today. Analysis of rocks at a formation named Wildcat Ridge revealed the organic compounds, which are made of carbon and other elements. "In the distant past, the sand, mud, and salts that now make up the Wildcat Ridge sample were deposited under conditions where life could potentially have thrived," said Ken Farley, the lead scientist for the mission.

Perseverance isn't designed to find life itself. However, it stored a sample of the delta material for return to Earth in about a decade. It will drop that sample, along with 11 others it had collected by late September, for retrieval by another mission. The sample-return mission will land in 2028. Current plans call for Perseverance to pick up the samples and carry them to the lander. If the rover is unable to perform that task, however, two small helicopters traveling with the lander will fetch them. A small rocket then will blast the samples into orbit for rendezvous with a larger rocket that will ferry them to Earth, in 2033.

InSight Discovers Ground Beneath Its Feet is Ice Free

While Perseverance has discovered evidence of a watery past in Jezero Crater, InSight, on a volcanic plain far from the rover, has found that its landing site is dry.

NASA/JPL/CALTECH

The Sun rises beyond InSight's robotic arm.

The stationary probe deployed a seismometer to listen for marsquakes. The seismic waves allow scientists to measure the properties of the ground beneath InSight to a depth of about 1,000 feet (300 meters). The observations reveal those layers aren't cemented together, but contain lots of open spaces, suggesting there is little or no ice. Other landers and rovers have found ice not far below the surface, so InSight's location is different from much of the Martian surface.

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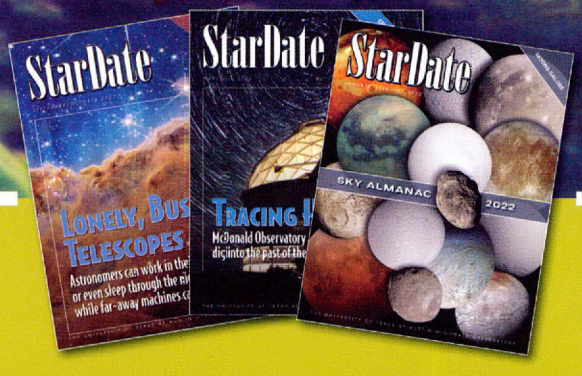

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Scientists combined images from Hubble Space Telescope and James Webb Space Telescope to produce this false-color view of the galaxy M74, which is about 32 million light-years away, in Pisces. New stars are being born in the bright pink knots that line the galaxy's spiral arms, while the old stars at the galaxy's heart are coded in blue and green. Red lanes in the spiral arms contain a lot of dust, with hotter dust shining orange.

ESA/NASA/CSA, J. LEE AND THE PHANGS-JWST TEAM; R. CHANDAR