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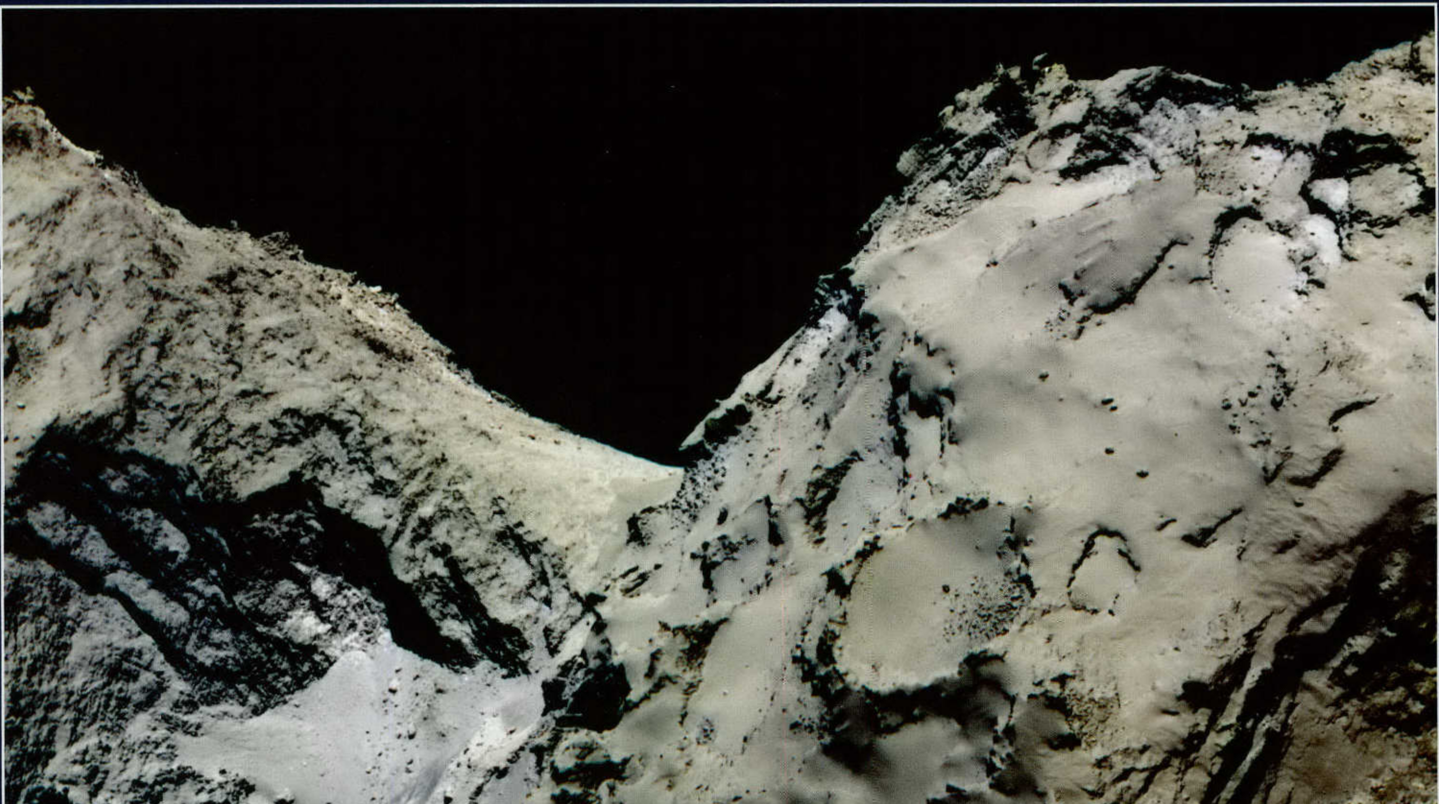
PLANET NINE? Page 4



SOLAR SYSTEM LEFTOVERS

Endings and beginnings for comet, asteroid missions

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Features

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ESA/ROSETTA/MPS FOR OSIRIS TEAM

On The Cover

A false-color image of Comet 67P/Churyumov-Gerasimenko shows an area that might be rich in water ice in blue, at bottom left. The Rosetta spacecraft, which took this image, is ending its mission to the icy solar system relic in September, while a mission to another relic — an asteroid — gets under way.

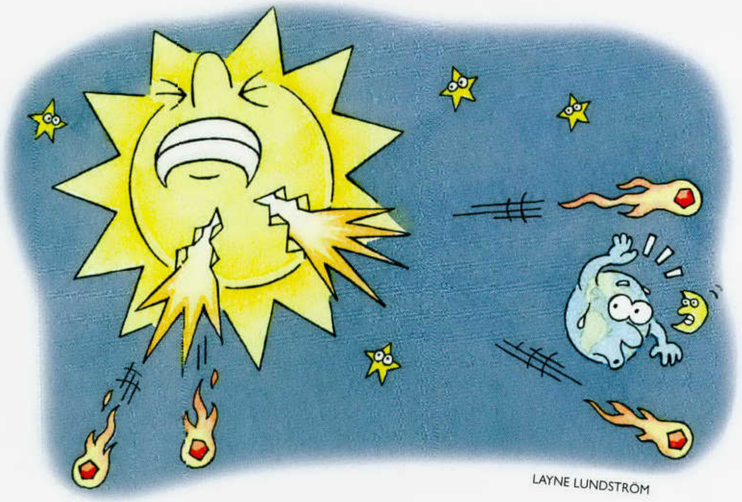
This Page

In this artist's concept of binary star AR Scorpii, a rapidly spinning white dwarf (top) accelerates electrons to almost the speed of light. Those particles blast the companion red dwarf star (bottom) with radiation, causing the entire system to pulse every 1.97 minutes.

Coming Up

In our next issue, see how an eclipse influenced a presidential election more than a century ago, and get up to date on Eta Carina, a closely studied star that could explode as a supernova.

MERLIN


LAYNE LUNDSTRÖM

Dear Merlin,

Is it possible that when a gigantic black hole reaches its maximum limit on how much material it can amass, it then explodes, releasing matter into space creating galaxies and/or small universes?

Richard H. Coppo
Lynchburg, Virginia

The modern-day understanding of black holes sounds like a Cole Porter song: Anything goes.

Some physicists speculate that, indeed, black holes could explode, creating new universes. Others say that black holes could explode, but without the new-universe-creation addendum.

Don't hold your breath while you wait for the fireworks, though. No stellar-mass black hole (one that formed from the collapse of a massive star) is likely to explode for trillions of trillions of years, while the supermassive black holes at the hearts of galaxies are likely to survive even longer.

Dear Merlin,

What would happen if the Sun were to explode?

Harry Burns
New York City

Bad things.

The explosion probably would destroy Earth, or at least wipe its surface clean, leaving behind a ball of bare rock. Then things would get dark and cold. And without the Sun as a gravitational anchor, Earth and the other planets would go hurtling into interstellar space.

Now that Merlin has scared you, let him add that the Sun will not explode. The only stars that explode are either much more massive than the Sun or they have close companion stars.

A star that is at least eight times as massive as the Sun eventually reaches a point where it can no longer produce nuclear reactions in its core. The core collapses, and the outer layers blast into space, forming a supernova.

A star like the Sun casts its outer layers into space more gently as it nears the end of its life (although perhaps with enough energy to disrupt nearby planets), leaving a dense, hot corpse known as a white dwarf. If the white dwarf has a nearby companion star, it may steal some of the companion's gas. If enough gas piles up, it triggers a runaway nuclear explosion that blasts the star to bits, also forming a supernova.

The Sun won't reach the white-dwarf stage for billions of years. As it ages, though, it is getting hotter and brighter. Within a billion years, it will bombard Earth with so much radiation that the planet's atmosphere and oceans will boil away into space. And a few billion years after that, the Sun will expand so much that it may engulf the remnant Earth, perhaps causing it to spiral in to the Sun's core.

So while the Sun won't explode, its future isn't very Earth-friendly.

Dear Merlin,

When I started teaching in 1977 there were 69 [known] moons in the solar system. How many moons are there today?

Don Lyles
Oakley, California

There are (probably) just as many moons today as there were in 1977 (although Merlin's numbers show only 32 known moons as of 1977). The only difference is that astronomers have seen many more of them.

Four decades ago, almost all of the known moons ranged from dozens to thousands of miles in diameter, so they were relatively easy to detect. The moons discovered since then are much smaller, and many of them are both dark and far away from their parent planet, making them even tougher to see. All of the new discoveries orbit the giant outer planets, which are a great distance from Earth, adding to the difficulties.

Even so, the numbers have been adding up. The Voyager 1 and 2 missions to the outer planets discovered a couple of dozen moons, with the Cassini mission to Saturn and Hubble Space Telescope adding more to the list.

The greatest number of discoveries, however, has come from two teams, one based at the University of Hawaii and the other in Canada. Using telescopes in Hawaii, Chile, and elsewhere, these two teams have racked up almost 80 discoveries.

With a few others nabbed by various researchers, that brings the total number of known moons for the solar system's eight major planets to 173 (only 149 have been named, however). Jupiter is the king of the moons, with 67.

Of course, these numbers don't include moons of the dwarf planets or asteroids. Pluto has five known moons, and astronomers recently discovered a small moon of Makemake, which is even farther from the Sun.

These discoveries suggest that the counting is far from over.

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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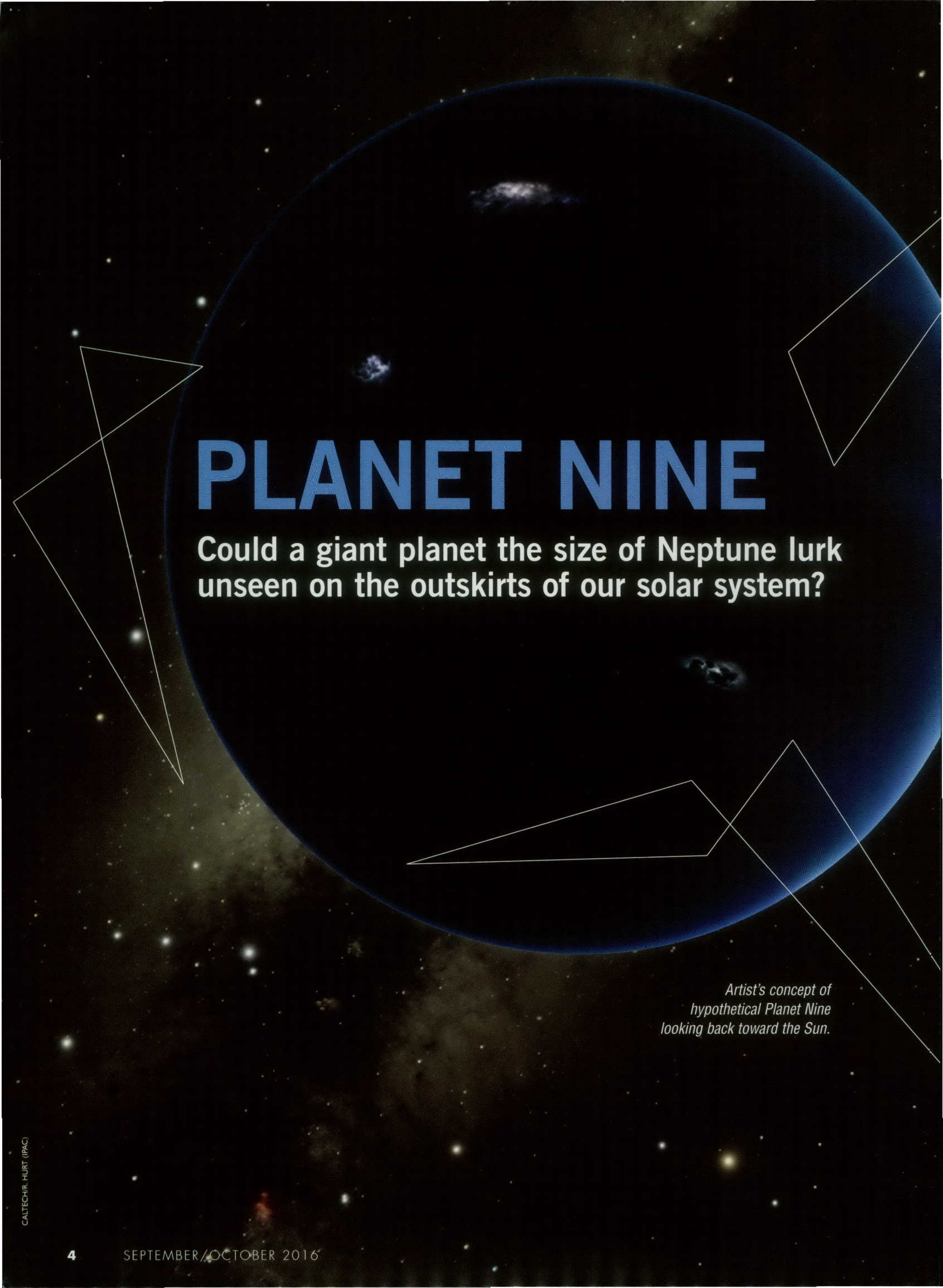


PLANET NINE

Could a giant planet the size of Neptune lurk unseen on the outskirts of our solar system?

Artist's concept of hypothetical Planet Nine looking back toward the Sun.

CALTECH/R. HURT (IPAC)

In January, Konstantin Batygin and Michael Brown of Caltech announced they had uncovered evidence of a previously unknown planet hiding out at the edge of our solar system. Thought to be an ice giant orbiting the Sun once every 10,000 to 20,000 years, astronomers have nicknamed it "Planet Nine." All that remains is to find it.

The first clue leading to the possible planet came in 2003, when Brown and his team discovered Sedna, one of the farthest dwarf planets yet discovered. At its closest, Sedna is 76 astronomical units (AU) from the Sun, which means it is 76 times farther from the Sun than is Earth. That is far beyond Neptune, the most remote major planet, and the even-more-distant Kuiper Belt, a ring of icy bodies whose most famous resident is Pluto. At its farthest from the Sun, Sedna reaches 937 AU — 31 times Neptune's distance! Brown was puzzled: Sedna lies far outside the influence of Neptune's gravity, so what could have pushed Sedna into its distant orbit?

Since then, scientists have uncovered more bodies on the outskirts of the solar system with similarly strange orbits. This year, Batygin and Brown were investigating 13 such objects in the Kuiper Belt and beyond when they made a major discovery: Of the 13 objects they were studying, the six most distant moved in the same direction, and their orbits were tilted at the same angle to the plane of the solar system.

This is unusual, as many Kuiper Belt Objects (KBOs) have odd orbits compared to the nearly circular, one-directional orbits of the major planets, which also fall into a shared plane. KBO orbits tend to be more elliptical and far-flung, often tilted at various angles to the plane of the solar system.

When Batygin and Brown found the six similar orbits, they immediately thought a massive object must have gravitationally nudged them into those orbits.

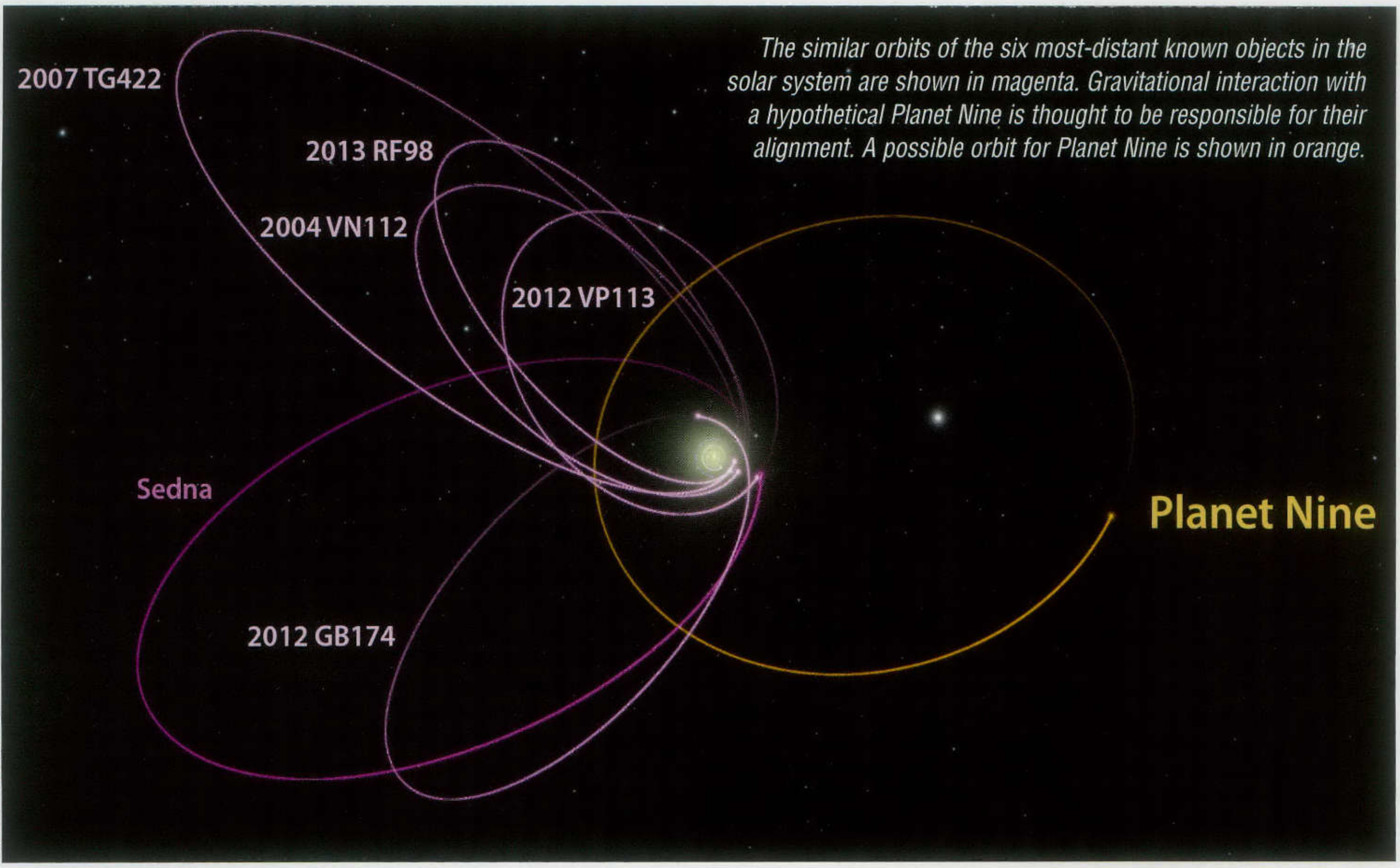
One explanation — that the Kuiper Belt itself contains enough mass to exert that kind of effect — was discounted immediately: Simulations showed the Kuiper Belt would need 100 times more mass than it's known to harbor.

Next, the scientists looked at whether an unseen planet could be influencing the six objects' orbits. They created a computer model that simulated such an influential planet, trying various masses and orbits. The model revealed a scenario that could cause the orbits of the six objects to align: a massive planet the size of Neptune traveling along an elongated orbit that is always on the opposite side of the Sun from the six KBOs. That is, the massive planet's perihelion (closest approach to the Sun) is 180 degrees away from that of the six KBOs.

Although no one has seen the hypothetical Planet Nine yet, Batygin and Brown say that its presence can be inferred by its effects on the six KBOs with aligned orbits. The chance of six KBOs having the same orbits by coincidence is pretty small — about one in 15,000.

"The most distant known objects in the Kuiper Belt have highly elliptical orbits that are aligned in physical space," Batygin said. "The only reasonable explanation for this clustering is the existence of a 10- to 20-Earth-mass planet that resides on an eccentric, inclined orbit that takes about 10,000 to 20,000 years to complete its journey around the Sun."

BY JASMIN FOX-SKELLY



The similar orbits of the six most-distant known objects in the solar system are shown in magenta. Gravitational interaction with a hypothetical Planet Nine is thought to be responsible for their alignment. A possible orbit for Planet Nine is shown in orange.

CALTECH/R. HURT (IPAC)

The scientists suggest that Planet Nine is able to influence the distant Kuiper Belt Objects — pushing them into orbits that point in the same direction and lie in the same plane — through a process known as orbital resonance. This is when two orbiting bodies exert a regular, periodic gravitational influence on each other.

"This type of interaction is analogous to how a child on a swing keeps the oscillation amplitude approximately constant — that is, by kicking at a particular point in the motion of the swing," Batygin said. "Over the lifetime of the solar system, Planet Nine has naturally selected objects that are on orbits that receive coherent gravitational tugs … . In doing so, Planet Nine has carved out a population of bodies that have orbits that all point in the same overall direction and lie in the same overall plane."

One of the most interesting aspects of the planet is what it could tell us about how the solar system formed. To understand that, scientists need to go back to the beginning and look at theories of how the planets were born.

The Sun formed from a cloud of gas and dust. As gravity pulled the gas molecules ever closer together, the center of the cloud compressed and heated up, eventually forming a star. The remains of this cloud surrounded the young star. As the Sun and the surrounding cloud rotated, the cloud flattened out into a disk around the newborn Sun.

Within the disk, small clumps of dust began sticking together, and eventually became massive enough to gravitationally attract matter until they grew into planets. Those closer to the Sun were small and rocky, as winds and radiation from the young Sun blew away most of the gas that surrounded them. Farther from the Sun, the rocky cores of planets held on to their surrounding gas, and became gas giants (in the case of Jupiter and Saturn) or ice giants (Uranus and Neptune).

It makes sense that Planet Nine would have formed on the outskirts of the disk, the astronomers say, but it could not have formed too far out, or there wouldn't have been enough matter in the disk to form a planet in the first place. Also, in its far-flung orbit, Planet Nine would have moved too slowly to gobble up enough gas to become a giant.

Batygin and Brown say they believe that the planet must have formed closer to the Sun than its current supposed locale, alongside Jupiter, Saturn, Uranus, and Neptune. Something must have then happened to send Planet Nine spinning off into its distant eccentric orbit.

Perhaps a young Planet Nine collided with another body in the early solar system, scattering both like balls on a billiard table. Alternatively, the gravity of one of the giant planets could have kicked Planet Nine into a new orbit. It might have been booted out of the solar system entirely, except as Planet Nine traveled along the disk, the gas and dust could have created enough drag to slow it down. If that was the case, it puts a time limit on when Planet Nine was kicked into its strange orbit: It must have happened when the solar system was between three million and 10 million years old, as after this the gas from the disk had dissipated.

Alexander Mustill, an astronomer at Sweden's Lund University, has another theory: Planet Nine is from another solar system. Mustill speculates that the Sun stole Planet Nine from another star system about 4.5 billion years ago, when the star could have passed closer to the Sun than any of its current neighbors.

Batygin says multiple processes could be at work. "It is likely that Planet Nine's highly elliptical orbit is a consequence of two processes that took place during the solar system's infancy: planets scattering off one another and gravitational perturbations from passing stars," he said.

"When Planet Nine is verified observationally, we will be able to place much tighter constraints on the environment in which planet formation took place within the solar system. Specifically, once its orbit is known precisely, we will be able to carry out numerical experiments that model Planet Nine's orbital history. Such simulations will shed light on just how violent of a place the young solar system was."

The matter likely won't be resolved until Planet Nine is definitively discovered — if it actually exists.

How will we know when Planet Nine is official? "The existence of Planet Nine will only be verified when its image is caught on camera," Batygin said. Finding it won't be easy, because it spends most of its time so far away. At distances from 600 to 1,200 AU, Planet Nine will be hard to spot with most telescopes. And since Hubble Space Telescope and others that observe vastly distant objects have incredibly small fields of view, it would take a long time to spot without first knowing where to look.

One telescope that might do the job is Subaru, an 8-meter telescope in Hawaii that can detect dim objects far away, but that has a wide field of view. Batygin and Brown have teamed up with other astronomers to hunt for the putative planet using this telescope.

Other teams, too, are trying to narrow down Planet Nine's location. Agnes Fienga and her colleagues at France's Côte d'Azur Observatory were analyzing data from the Cassini space probe when they realized that abnormalities in Saturn's orbit could be explained by the gravitational pull of Planet Nine. This means that Cassini data could also be used to tell us more about where the planet could be — or, more accurately, where it can't be. Fienga used the orbit proposed by Batygin and Brown and found that she could rule out the planet's current location being anywhere along about half of the proposed orbit. If Planet Nine were there, its effects would have shown up in Cassini data.

Matthew Holman and Matthew Payne of the Harvard-Smithsonian Center for Astrophysics have taken this idea farther. They modeled several potential orbits for Planet Nine and compared them to the Cassini data. Based on their findings, they say that the planet is in the constellation Cetus. Although that area is still quite large (5,000 times the size of the full Moon), it does provide a starting point.

Resources

Internet

The Search for Planet Nine
findplanetnine.com

Hypothetical 'Planet X'
solarsystem.nasa.gov/planets/planetx

Kuiper Belt Obects
space.com/16144-kuiper-belt-objects.html

If and when it is found, various types of observations could tell us what conditions are like on Planet Nine. Calculating its orbit could tell us how the planet formed, and a measurement of its albedo — the amount of sunlight it reflects — could reveal its chemical makeup.

To some, the most important question is what it would be named. That's up to the International Astronomical Union, whose Committee on Planetary Nomenclature would choose a name from Greek or Roman mythology.

Whatever the name, the potential verification of Planet Nine shows us that we still have exciting things to learn in the coming years about worlds in our own cosmic backyard.

Jasmin Fox-Skelly is a freelance science writer in Wales.

Distant Discoveries

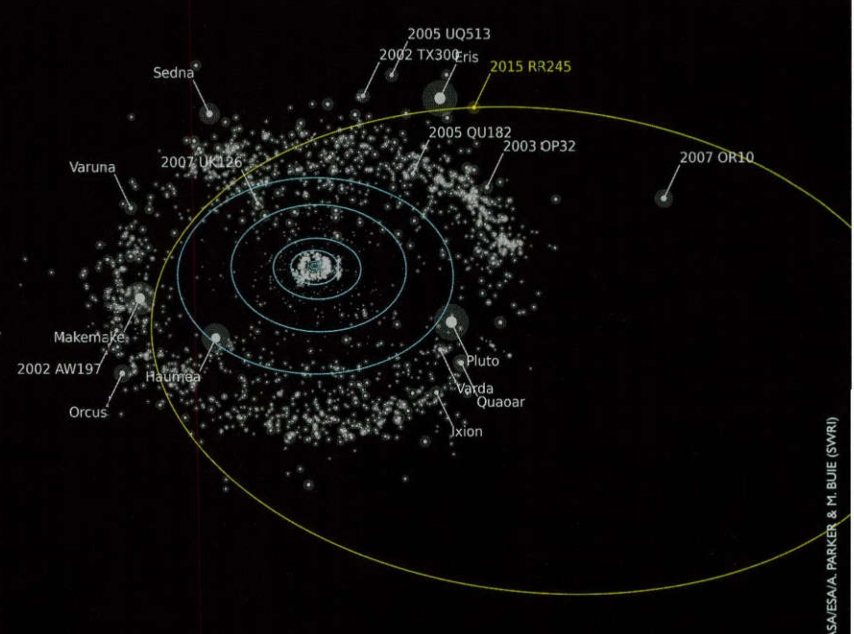
While Planet Nine is still just a hypothesis, astronomers have definitely discovered a few new worlds in the distant solar system lately: a new dwarf planet, and a moon for a previously known dwarf planet.

Announced in July, the new dwarf planet is known as 2015 RR245. J.J. Kavelaars of the National Research Council of Canada first spotted it, going over images from the Outer Solar System Origins Survey taken with the Canada-France-Hawaii Telescope.

RR245 is about 435 miles (700 km) wide, and has one of the largest orbits yet seen for a dwarf planet. It takes this small world 700 years to orbit the Sun on its highly elliptical track. Currently traveling toward the Sun, RR245 will reach its closest approach around 2096.

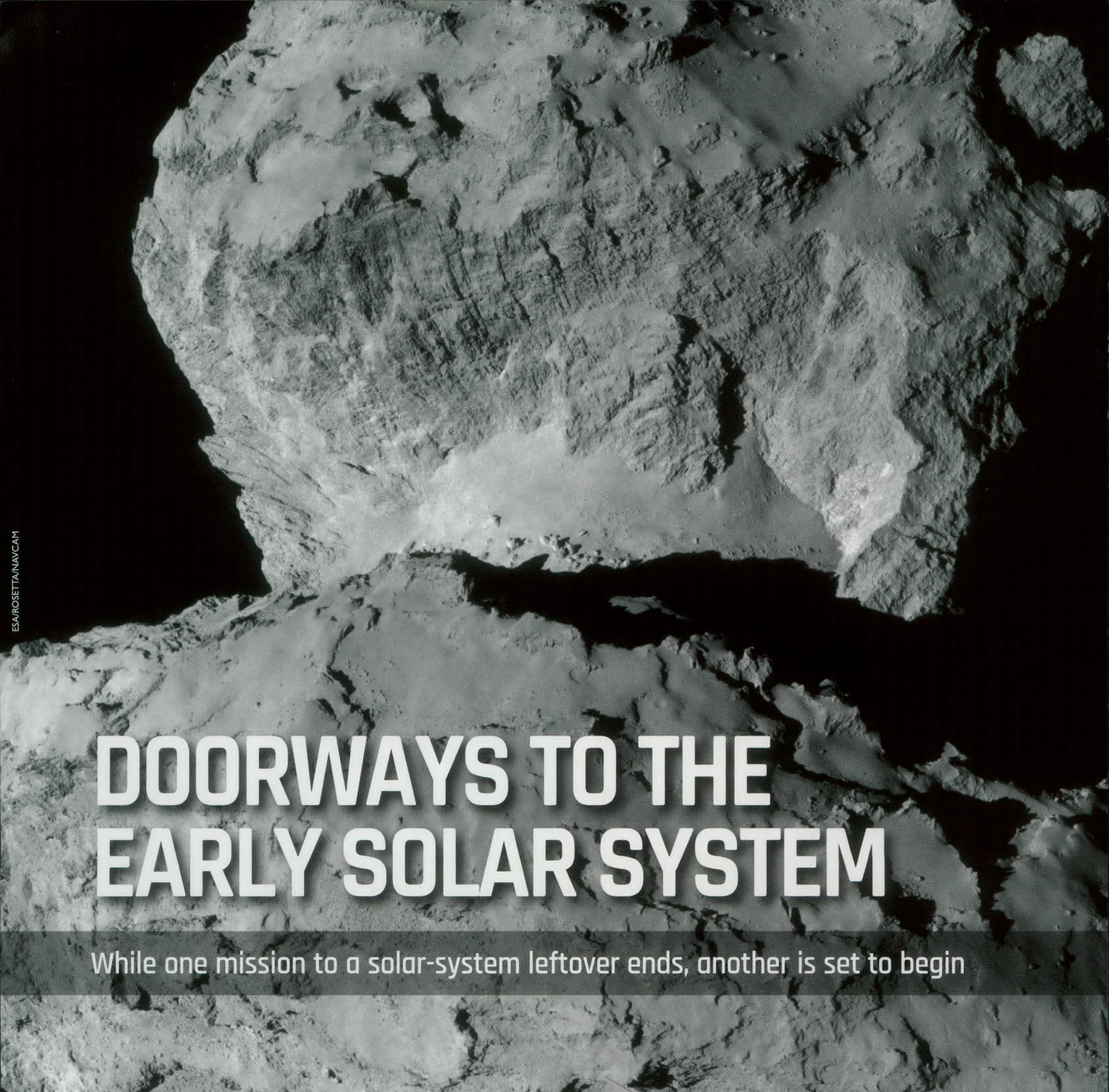
The discovery team said in a statement that the world's precise orbit will be refined in the coming years, after which RR245 will get an official name.

In April, Alex Parker of the Southwest Research Institute used Hubble Space Telescope to discover that Makemake, the second-brightest dwarf planet, has a moon. Nicknamed MK 2, the moon is 1,300 times fainter than Makemake. The moon is about 100 miles (160 km) wide, compared to Makemake's 870-mile (1,400-km) diameter. **RJ**



A. PARKER/OSSOS TEAM; NASA/ESA/A. PARKER & M. BUIE (SWRI)

The orbit of RR245 (yellow) takes it far afield of the major planets (blue). Dwarf planets and Kuiper Belt Objects as bright or brighter than RR245 are labeled.

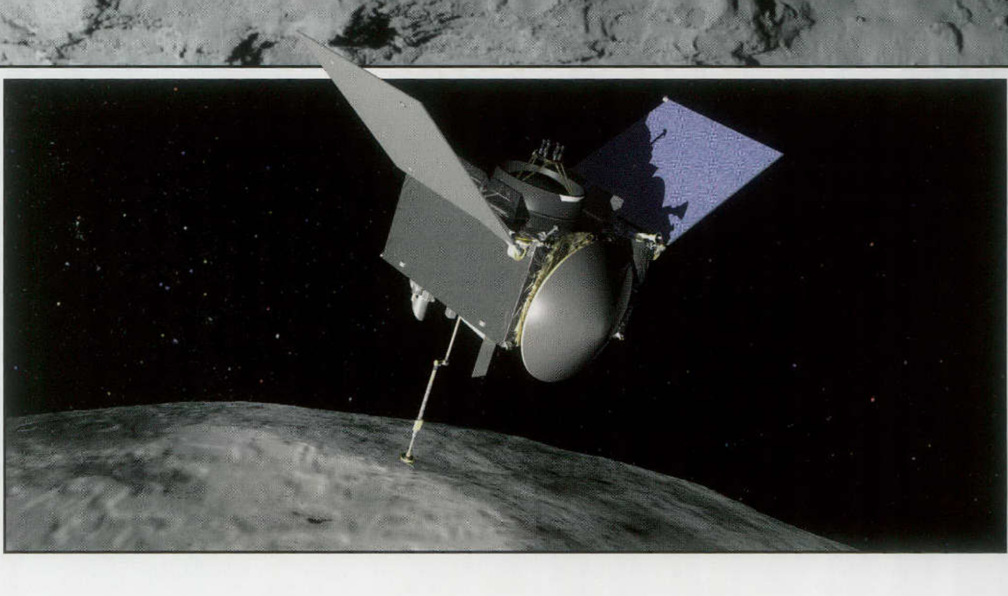


ESA/ROSETTA/NAVCAM

DOORWAYS TO THE EARLY SOLAR SYSTEM

While one mission to a solar-system leftover ends, another is set to begin

Above: A close-up view of 67P/Churyumov-Gerasimenko shows its two separate lobes. Right: Artist's concept of OSIRIS-REx making contact with Bennu. Opposite page: An overall view of 67P shows gas and dust jetting into space.



NASA

Planetary scientists may be thinking of the words of Alexander Graham Bell as September rolls by: "When one door closes, another opens." One door on the birth of the planets will close at month's end. By then, however, another should be cracking open.

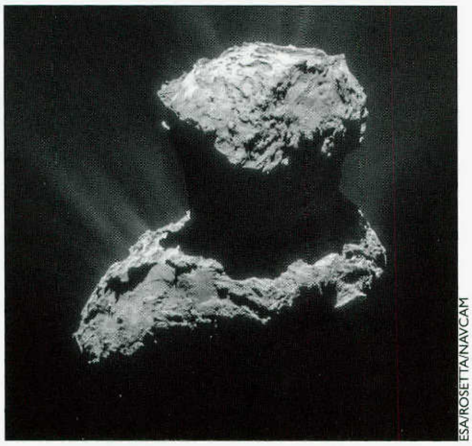
The first door is scheduled to close on September 30, when Rosetta touches down on Comet 67P/Churyumov-Gerasimenko. The European craft began orbiting the comet in August 2014. Rosetta tagged along as the comet passed closest to the Sun, where the Sun's heat warmed its outer layers, spewing gas and dust into space. Rosetta also deployed Philae, a probe designed to land on the comet, but it landed awkwardly and soon expired.

Even so, Rosetta revealed a great deal about Churyumov-Gerasimenko, which, like all comets and asteroids, is a likely leftover from the formation of the planets, roughly 4.5 billion years ago. Studying such objects can reveal details about the disk of gas and dust around the young Sun that gave birth to Earth and the other planets, and how that material came together to form larger bodies.

Rosetta found that Churyumov-Gerasimenko is shaped like a rubber duck, with two lobes joined by a narrow neck. A recent study found that the lobes may have split apart and come back together many times over the comet's history.

Rosetta also measured the comet's composition. It detected an amino acid and other compounds that are important for life, suggesting that comets might have delivered some of the ingredients for life to Earth. On the other hand, the craft found that the water on Churyumov-Gerasimenko doesn't match the water on Earth. That might mean that comets did not supply most of the early Earth's water, as many scientists have long suggested.

During September, Rosetta will drop closer and closer to the comet, then touch down. It will snap pictures and take other readings along the way. It is not designed as a lander, however, so


ESA/ROSETTA/NAVCAM

its solar arrays won't be able to gather sunlight and its radio antenna won't be able to aim at Earth, bringing its mission to an end.

By then, however, the second door is scheduled to open, with the September 8 launch of the torturously named Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (OSIRIS-REx). It is scheduled to rendezvous with the asteroid 101955 Bennu, another relic of the solar system's formation, in 2018. After a long period of reconnaissance, it will touch down, scoop up anywhere from a couple of ounces to a few pounds of the asteroid's powdery surface dust (known as regolith), then return the material to Earth in 2023.

"The first job in the mission is to try to identify materials that might be representative of the materials that the solar system was originally constructed from," says Ed Beshore, the mission's deputy principal investigator and an astronomer at the University of Arizona. "So what we expect to find at our target asteroid is very pristine, very ancient solar system material that has not been processed."

Bennu also is of interest because it's on the list of potentially hazardous asteroids, with a roughly one-in-a-thousand chance of hitting Earth late in the 22nd century. "It is one of the most threatening of all asteroids right now," says Beshore. "It's about a 500- to 600-meter-wide asteroid, and because of that, if it did hit the Earth, it would actually be a pretty destructive event. It probably wouldn't be a civilization-threatening event, but it would be catastrophic.

"If we actually do find an asteroid that's on an inbound trajectory, if we have the luxury of time, we're going to send a spacecraft to it because we will want to know the things we need to know in order to mitigate that impact. ... So, in many ways, the OSIRIS-REx mission is going to be an important prototype and is going to develop important technologies for how we work around a small body."

— Damond Benningfield

Sky Calendar

by Alan MacRobert

Fall brings crisp days, turning leaves, and its own signature constellations. By September's end, each nightfall brings winged Pegasus into good view, with Andromeda to its left. Venus, the Evening Star, climbs in the west at sunset. Mars starts to pull away from Antares and Saturn, though not by much. By mid-October, Jupiter is climbing into view at dawn.

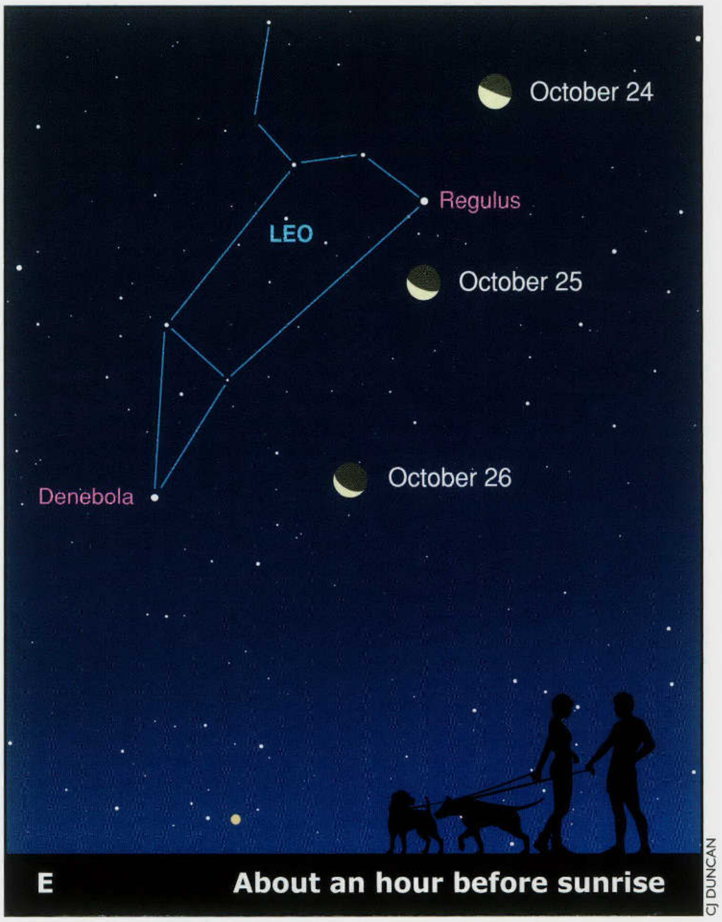
SEPTEMBER 1 - 15

Mars, Saturn, and Antares still grace the dusk toward the south as summer starts to wane. The big triangle they make has been this summer's defining celestial landmark.

But the triangle is constantly moving and changing shape. On August 23 and 24, in fact, it narrowed down to an almost vertical line. Mars now shines to the left of the other two, after its August pass between them. It's still the brightest of the three. Antares is the faintest, lowest, and most twinkly. The Moon poses over them on September 8 and 9.

Mars will keep moving ever farther to the left of Saturn and Antares, lengthening the triangle as it travels east against the westward seasonal turning of the celestial background. This will continue until Saturn and Antares sink into the sunset in November. Fast-flying Mars won't be dragged down into the sunset until early next spring.

Look to the right of Antares, by less than a fist-width at arm's length, to find the next-brightest star in the region: Delta Scorpii, a variable that flared up to its current brightness 16 years ago. Delta Scorpii turns the Mars-Saturn-Antares triangle into a quadrilateral. On September 6, the four of them form a symmetrical diamond shape, elongated and lying almost on its side. That evening, the waxing crescent Moon marks the way from well to their right. On September 8 and 9, it passes above the diamond.



What about the other planets? Mercury, Venus, and Jupiter are all lost in the bright sunset. Uranus and Neptune lurk invisibly dim from quite low in the east and southeast, respectively.

About an hour after sunset, as the stars come out, look straight up for Vega passing the zenith. (It passes exactly through the zenith if you're at latitude 39 degrees north.) This "summer star" has spent the spring and summer climbing to reach its twilight high point just as summer nears its end. More on this in a bit.

Arcturus, Vega's match for brightness, shines lower in the west. And wherever Arcturus resides, the Big Dipper is not far away. Look for it now to Arcturus' right, in the northwest. The dipper is starting to level out for its low, cold-weather passage under the north celestial pole.

Meanwhile, in the northeast, Cassiopeia now rises high. Its flattened-W pattern tilts up more and more onto its dim end as evening grows late.

Look due east, farther to the right of Cassiopeia, for the Great Square of Pegasus standing tipped up on one corner.

SEPTEMBER 16 - 30

The Mars-Saturn-Antares triangle grows longer and longer as it tilts down toward the southwest at dusk. Add in Delta Scorpii, glimmering to the right of Antares, and now you've got a long, narrow kite lying on its side. Mars is where the tail would be tied on.

And speaking of kites, Arcturus (due west at nightfall) is the tail end of the wider, permanent kite pattern of Boötes, the herdsman. Find it extending to the upper right from Arcturus. It's about two fists tall.

After sunset, it's time to start looking for Venus quietly creeping onto the evening stage. Venus is emerging from behind the Sun's glare in the west-southwest. It's still very low above the horizon, but its brightness makes it visible closer to the Sun than any other star or planet. If you have a clear view low in the west-southwest, start looking about 20 minutes after sunset. Binoculars or a low-power telescope should pick up Venus fairly easily — unless a wisp of distant cloud happens to be in the way. Don't wait too long, or the planet will set.

Venus becomes easier to see each evening, first gradually for the next few weeks, and then with increasing speed in late October. By December, Venus will dazzle the world from stage southwest as the Evening Star in twilight — a dramatic performance that it will continue all winter.

Summer officially ends on September 22 this year, at the equinox moment of 9:21 a.m. CDT. This is when the Sun crosses the equator heading south for the season.

The September equinox is also about when Vega yields the title of "zenith star" to its neighbor Deneb at twilight's end. Deneb, not quite as bright, is pushing Vega aside from the east. It happens like clockwork every year.

High in the south at the end of twilight, look for the third-brightest star of the September dusk: Altair. Just 17 light-years from Earth, Altair is the sharp eye of Aquila, the eagle. You'll find it three or four fists below Vega and Deneb. The three of them form the Summer Triangle, culminating as summer ends.

Meteor Watch

The Shower

Orionids

Named for the constellation Orion, which is notable for its three-star belt and for the Orion Nebula, which is visible below the belt as a hazy smudge of light. At its best, this shower produces perhaps 15-20 meteors per hour.

Peak

Night of October 21

Notes

The gibbous Moon will be in view most of the night, wiping out all but the brightest meteors.

OCTOBER 1 - 15

Mars holds steady in the south-southwest in late twilight from week to week. But it's fading as Earth leaves it behind. The Red Planet is a small thing now compared to its dazzle around closest approach last May. Watch the Sagittarius teapot slide below it during the first three weeks of October.

Saturn and Antares, now low on the horizon in the southwest, have clearly said their goodbyes to Mars for this year. Now this pair has its eyes on another prospective companion: Venus, which is becoming easier to see in twilight far to their lower right. These three are forming into a triangle of their own, which will rapidly shorten until Venus slingshots right between the other two in late October, just as Mars did in late August.

In the northeast, look for Cassiopeia climbing ever higher as the weather turns chilly. It's the best-known star pattern after Orion and the Big Dipper. Cassiopeia's flattened W is now tipping up on end, with its brightest part on top.

Below Cassiopeia, Perseus is nosing upward. Both constellations lie along the Milky Way, making them rich in stars both bright and faint. Even under urban light pollution, good binoculars will reveal some of their faint starry richness.

Look to the right of Cassiopeia and Perseus, due east, for big Andromeda and Pegasus. The three brightest stars of Andromeda form a long, slightly curving line that rises a little upward from left to right. The rightmost one doubles as the left corner of the Great Square of Pegasus. Each bright star in the big arrangement is separated from its neighbors by a little more than a fist at arm's length.

And an open view to the north-northeast reveals bright Capella sparkling vigorously as it rises — a winter star making its early debut.

OCTOBER 16 - 31

Fall is Fomalhaut's time to shine. It's the only really bright star in the southern sky on late-autumn evenings. At nightfall, you'll find it low in the south-southeast. Later in the evening it culminates in the south.

Look above Fomalhaut for big, dim, scraggly Aquarius. You'll need a good constellation chart and a dark sky to piece out its complicated pattern of a stick figure in profile running leftward and carrying a spilling water bucket in front of him.

As fall advances and cooler weather moves in, watch the Big Dipper swing low in the north-northwest. Pretty soon it's lying horizontal, with its bowl to the right and its bent handle to the left.

Bright Arcturus, left of the Dipper, is nearing its seasonal departure, twinkling forlornly lower and lower in the west-northwest in late twilight.

Vega, meanwhile, has shifted well to the west of overhead. With Arcturus on the way out, Vega takes over as the single brightest star in the western sky.

Altair shines a little less brightly, high in the southwest. Above Altair after dark, about one fist from it, are two small but distinctive constellations. To the upper left of Altair lies Delphinus, the dolphin, leaping in the edge of the Milky Way. To Altair's upper right by just a little less, see if you can spot Sagitta, the arrow, even smaller and dimmer. You'll need a fairly dark sky. The arrow, like the nose of the dolphin, currently points to the upper left. I wonder what they're both aiming at?

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

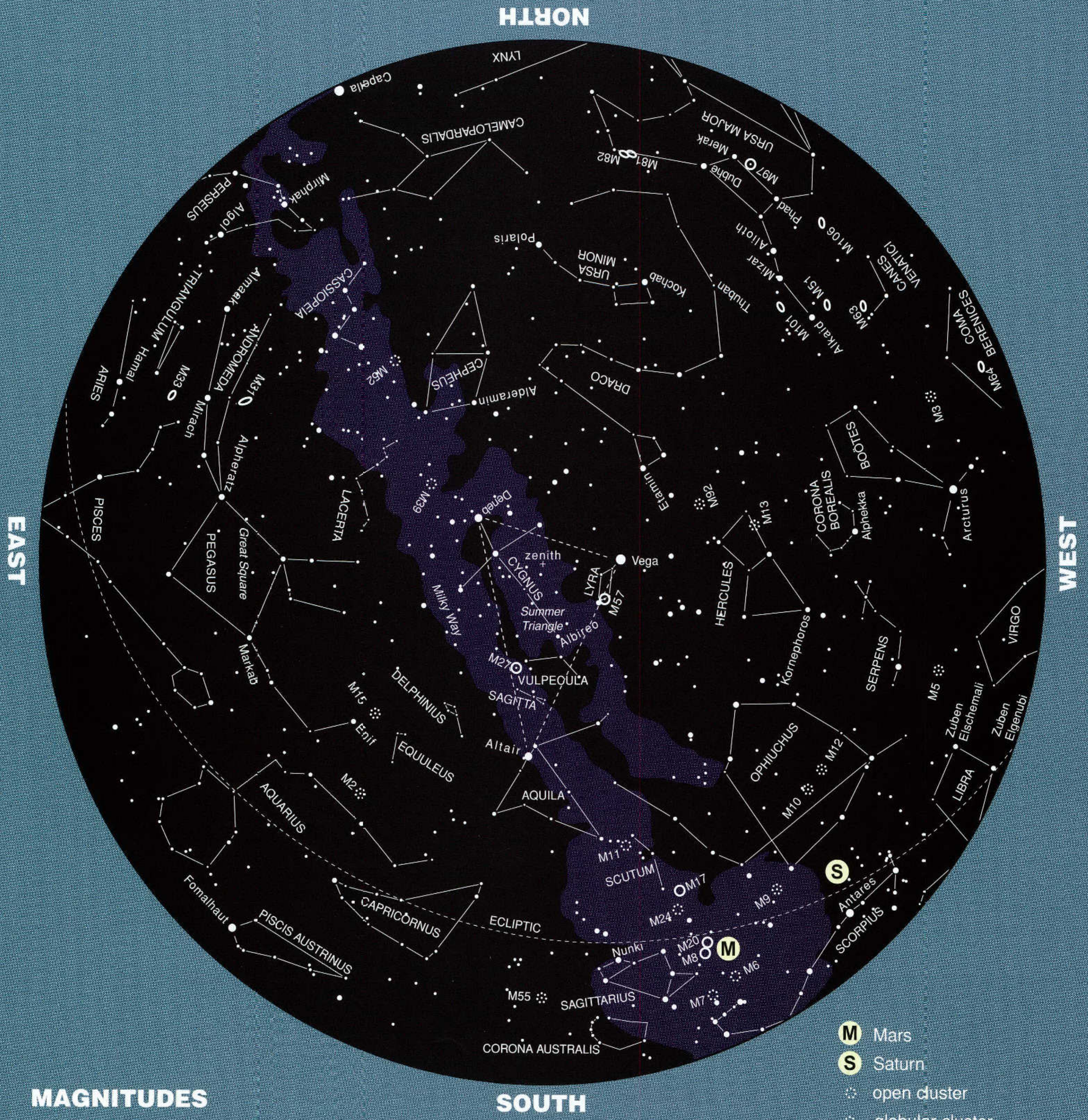
A Spirited Change of Seasons

Halloween is a modern commemoration of a cross-quarter day, which falls between a solstice and an equinox. In many cultures, these dates represented the start of a new season, not its mid-point. In Ireland, the start of winter was a dreaded time of year, when lost souls roamed the land, looking for new bodies to inhabit. On November 1, All Saint's Day, priests lit bonfires to scare away the spirits, and people dressed as goblins, made loud noises, and played pranks to convince the spirits that they were already possessed. Irish immigrants brought the tradition to the United States in the 1800s, and the customs of Halloween remain with us today.

SEPTEMBER

How to use these charts:
1. Determine the direction you are facing.
2. Turn the chart until that direction is at the bottom.

August 20 11 p.m.
September 5 10 p.m.
September 20 9 p.m.



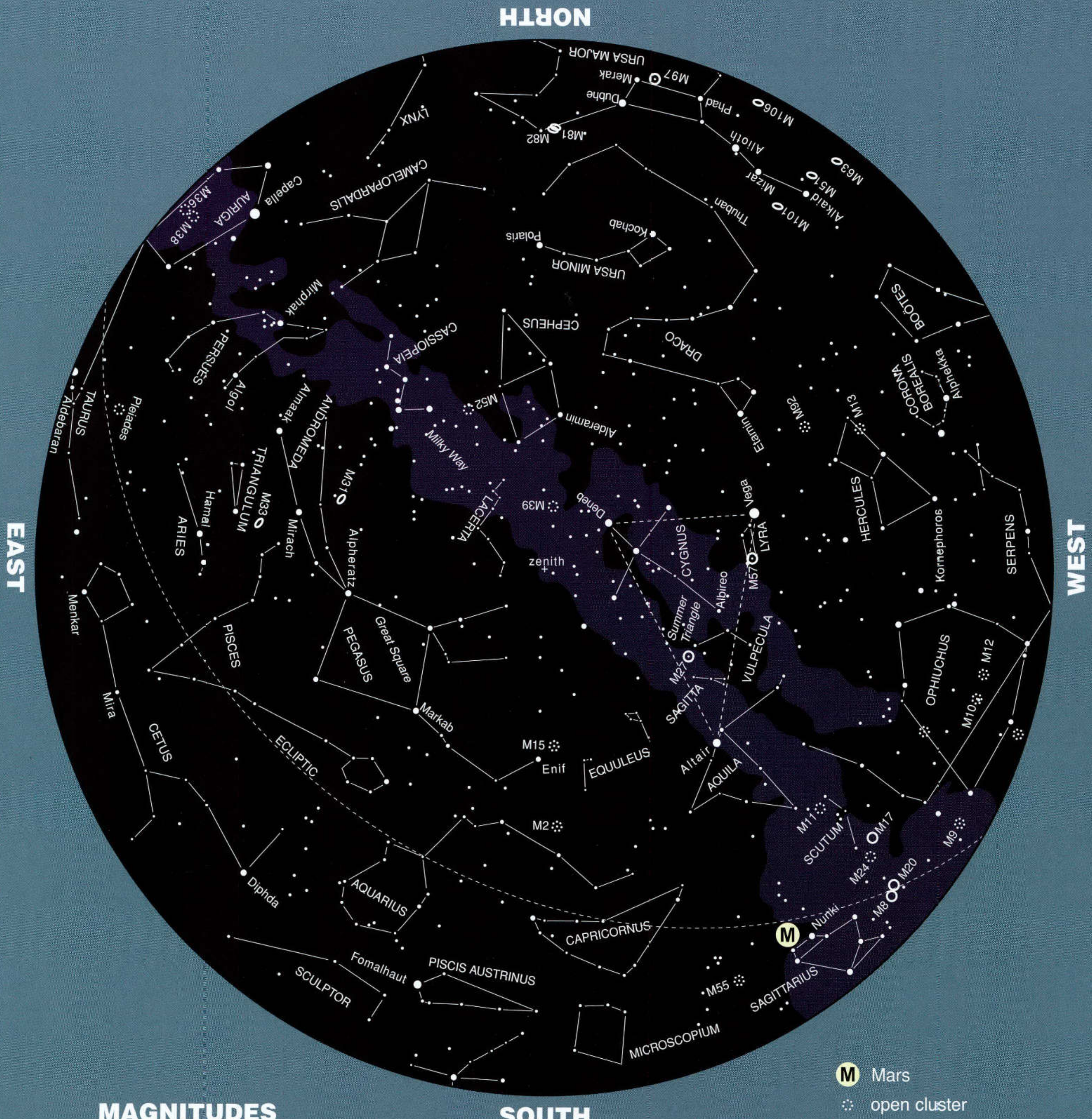
MAGNITUDES
- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

M Mars
S Saturn
open cluster
globular cluster
nebula
planetary nebula
galaxy

OCTOBER

How to use these charts:
1. Determine the direction you are facing.
2. Turn the chart until that direction is at the bottom.

September 20 **11 p.m.**
October 5 **10 p.m.**
October 20 **9 p.m.**



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

Ⓜ Mars
open cluster
globular cluster
nebula
planetary nebula
galaxy

By the Numbers

New book explains how astronomers discovered the age of the universe

In the late 19th century, astronomers and geologists were locked in a bit of a squabble. Geologic evidence suggested that Earth was at least one billion years old. Astronomers dismissed that age, however, because they could find no way to make the Sun shine for that long. One idea was that asteroid impacts heated the Sun, but such a process couldn't power the Sun for more than a few thousand years. Another was that the Sun was heated by gravitational contraction, which would extend the Sun's lifetime to perhaps 100 million years.

The difference between the sciences wasn't settled until the 1930s, when astronomers discovered that the Sun and other stars are powered by nuclear fusion, in which atoms of hydrogen fuse to form helium. The Sun is so massive that it has sustained fusion reactions for 4.6 billion years, and has enough hydrogen to shine for several billion years longer.

Measuring the age of Sun and Earth was an important step in determining the age of the universe. Only in the last couple of decades, in fact, have astronomers settled on a number: 13.8 billion years.

That age forms the title of a new book by cosmologist and author John Gribbin. *13.8: The Quest to Find the True Age of the Universe and the Theory of Everything* ($30, hardback), provides a well-written, easily understandable history of the lengthy and complex effort to decipher the age and history of the universe.

Gribbin recounts how Edwin Hubble, building on the work of many others, demonstrated that glowing pinwheels of matter are actually galaxies far beyond the bounds of the Milky Way, and that most of these galaxies are moving away from us. He details how astronomers discovered that the motion is the result of the expansion of space itself — a result of the Big Bang. And he explains how two radio astronomers at Bell Laboratories provided strong confirmation of the Big Bang by discovering the cosmic microwave background — the faint "afterglow" of the Big Bang, which permeates all of space.

This step-by-step recounting lays out the case for the Big Bang and the age of the universe — a number that all scientists can agree on. **DB**

Take a Bite Out of Space

Want insight into astronomy research on the cutting edge? The long-running blog Astrobites provides short synopses of research papers that have been submitted to professional astronomy journals. Graduate student volunteers from universities around the world write the summaries at a level for college students with no particular astronomy knowledge. A new article is posted each day. The blog has been around for six years. In June, the American Astronomical Society announced that it will now sponsor Astrobites, to ensure that it continues.

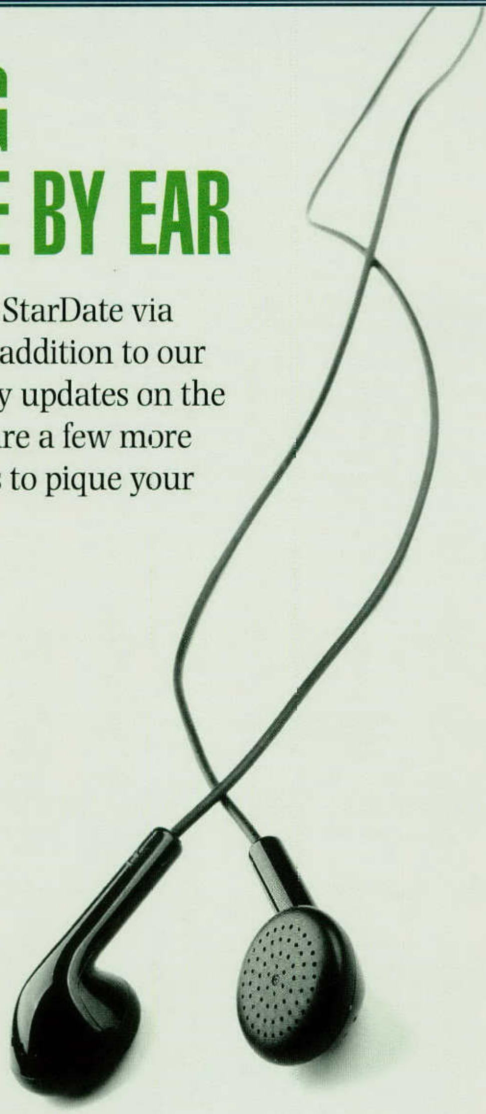
astrobites.org

ASTROBITES

by Damond Benningfield and Rebecca Johnson

PLAYING SCIENCE BY EAR

Do you enjoy StarDate via podcast? In addition to our two-minute daily updates on the night sky, here are a few more science podcasts to pique your interest.



The Discovery Files

The Discovery Files is a minute-long podcast featuring a fun look into science and engineering funded by the National Science Foundation (NSF). Several new episodes are released each month. Listen to the free podcast online at NSF's multimedia gallery or subscribe via iTunes.

nsf.gov/mmg

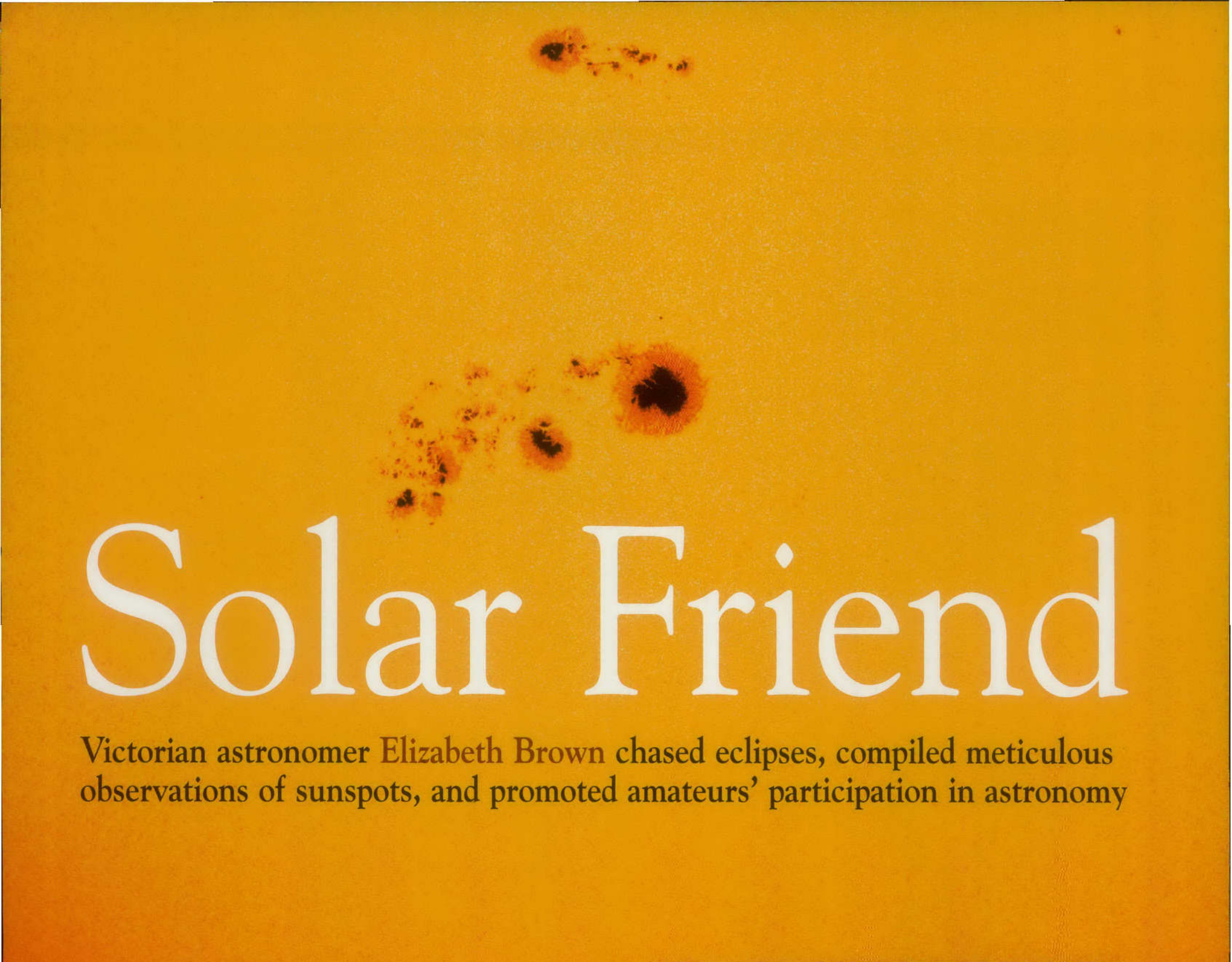
Science Sessions

Produced by the National Academy of Sciences, the free monthly Science Sessions podcast brings information from a variety of topics in science and engineering, from astronomy to vaccines and from glaciers to genomes. Each episodes runs approximately five minutes and features a conversation with a researcher. Listen to programs online, or subscribe on iTunes.

pnas.org/site/podcasts/podcasts.xhtml

Filling in the Night Sky

Princeton Architectural Press has produced a new tool for skywatchers who like to log their nights under the stars. *Observer's Notebook: Astronomy* ($18.95), offers 160 blank, lined pages for recording your personal discoveries: double stars, galaxies, nebulae, or any other favorite targets. It also includes a section for filling in the phases of the Moon, and pages for drawing observations made through binoculars or a telescope. Section dividers offer star charts, descriptions of eclipses, information on the planets of the solar system, and more. The notebook will go on sale October 4.



Solar Friend

Victorian astronomer Elizabeth Brown chased eclipses, compiled meticulous observations of sunspots, and promoted amateurs' participation in astronomy

RAS/SCIENCE SOURCE

Several groups of sunspots crawl across the Sun. The largest are bigger than Earth. Right: Elizabeth Brown at the telescope.

NASA/SDO

Sunspots are pretty well understood these days. They are dark areas on the Sun where strong lines of magnetic force restrict the flow of hot gas from below, keeping them cooler than their surroundings (though they still sizzle at temperatures of thousands of degrees). Many are larger than Earth, and some are as big as Jupiter, the solar system's largest planet. They move from east to west, in the direction of the Sun's rotation. The number of sunspots waxes and wanes in an 11-year cycle that's caused by a flip in the Sun's magnetic poles. And those cycles vary in intensity, with some producing enormous eruptions of sunspots and others seeing barely a dot on the Sun's brilliant face.

Yet it's taken centuries for astronomers to compile that dossier on sunspots. They didn't begin studying them in detail until after the invention of the telescope, which allowed them to map the cool magnetic storms in detail and trace their paths and their evolution. Much of our modern understanding developed in the 19th century, when several astronomers — professional and amateur alike — began devoting much of their careers to studying the Sun and its puzzling spots.

"I think that part of it was, they realized that the Sun is the closest star to us, and if we ever hope to understand the stars, we have to understand our Sun," says Kristine Larsen, an astronomer at Central Connecticut University and president of the American Association of Variable Star Observers. "Also, you had a lot of changes in technology and our understanding of physics going on at the end of the 1800s. You had the introduction to spectroscopy, you had the introduction to photography, and so you could actually get more information and keep a nice careful record."

One astronomer who helped launch the new investigations of the Sun was Elizabeth Brown, an amateur who devoted much of her life to studying sunspots.

Brown was born on August 6, 1830, the elder daughter of Jemimah Brown and Thomas Crowther Brown, a wine merchant. Her birthplace and lifelong home was Further Barton, Cirencester, a wool-producing market town in Gloucestershire in southern England.

The young Elizabeth and her sister, Jemima, played with their cousins and pets, took lessons with governesses, and visited relatives and the seashore. Their mother died before Elizabeth's eleventh birthday. Elizabeth was close to her father, who taught her how to observe the sky for meteorological information and how to use a small hand-held telescope to view Saturn's rings and Jupiter's moons. As her fascination with astronomy grew, she learned to identify stars and to understand astronomy literature. After her formal education with governesses ended, she read widely on her own, especially in the sciences and literature, and began developing her artistic ability.

Her father was a dedicated amateur meteorologist and a Fellow of the Geological Society. Together, he and Elizabeth recorded daily rainfall for the Royal Meteorological Society. Elizabeth later continued the work, visiting the rain gauges each day at 9 a.m. and recording temperature, thunderstorm activity, and other information.

Beginning in 1881, Brown published letters describing her observations of auroras, sunsets, the zodiacal light, rime and mist, and other astronomical and meteorological phenomena.

By Maria Chiara

Like many others, she was struck by the dramatic sunsets that occurred for months after the 1883 eruption of Krakatoa, a volcano in Indonesia, between Java and Sumatra. The vast amount of ash and dust ejected into the stratosphere produced strange visual effects worldwide, such as green and blue Suns in tropical areas and lingering sunsets in the British Isles. Brown's report was incorporated into the Royal Society's 1888 report, *The Eruption of Krakatoa, and Subsequent Phenomena.* That enhanced her growing scientific reputation, which, in 1893, led to her election as a Fellow of the Royal Meteorological Society, an honor she highly prized.

When her father's health failed, Elizabeth cared for him until his death in 1883. Afterward, she began to travel and to devote herself more fully to astronomy. She began using her father's telescope, a 3-inch refractor, to study the Sun, Moon, and planets. Later, she owned a larger refractor, a 6½-inch reflector, a grating spectroscope (for analyzing the light of stars and other objects), and an astronomical clock.

The telescopes were housed in one of two private observatories on the grounds of her home; the other contained her meteorological instruments. According to her biographer, Mary Creese, Brown probably was the only woman of her day in Britain to have her own observatory. Because of her delicate health, though, she generally avoided night observing and concentrated on the Sun. She observed sunspots by projecting the Sun's image onto a sheet of white cardboard, darkening the room, and tracing any visible spots.

In December 1893, Brown presented her first paper on the subject, to the flourishing Liverpool Astronomical Society (LAS), "Observations of proper motions in certain sunspots." Shortly after that meeting, the LAS elected her to membership and invited her to become director of the society's solar section.

Her reports, published in the society's *Proceedings* and *Journal*, examined the structures of sunspots and sunspot groups and their positions and movements on the Sun's face. For example, one report described a sunspot group that was notable for its sudden growth, long duration, elliptical form, and other characteristics.

"Elizabeth Brown was one of these devoted amateur astronomers who was very much in love with what she did," says Larsen, who has studied Brown's contributions to the field. Brown not only made her own observations, Larsen notes, but she encouraged others to watch the Sun and to add their observations to the growing body of work on sunspots. She compiled those observations to create records for analysis by leading solar astronomers.

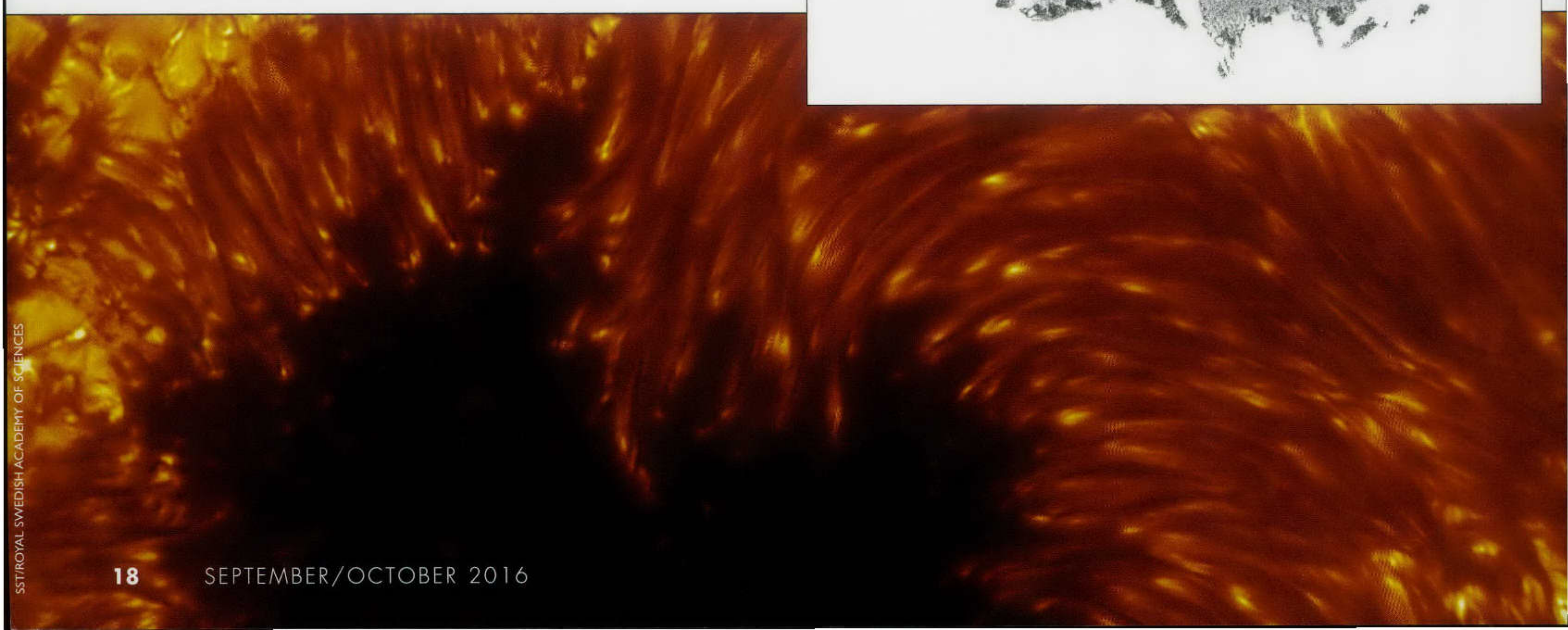
"We've only really known that there was a sunspot cycle since the 1800s," says Larsen. "So it's not something that's completely understood. And so all of those observations were very, very important in trying to further our understanding of the sunspot cycle."

As a member of the LAS's star color section, Brown also studied variable stars, which grow brighter and fainter over predictable periods of time, and stars that appeared to change color. She urged amateurs, especially those with small telescopes, to aid in the search for Vulcan, a hypothetical planet inside the orbit of Mercury that was expected to become visible when it crossed in front of the Sun.

During her years with the LAS, Brown made two expeditions to observe total solar eclipses, becoming the first woman to be part of a scientific eclipse team. She wrote lively popular accounts of her ventures, both published as "A Lady Astronomer." Her first book, *In Pursuit of a Shadow*, captured the excitement she and her young companion "L" (her cousin Louise Jeffreys) felt as they began their journey to Kineshma, a village in Russia 200 miles northeast of Moscow, to observe the

One of Brown's sunspot illustrations, from an 1892 issue of the British Astronomical Association's journal; below, one of the best modern views of a sunspot.

BRITISH ASTRONOMICAL ASSOCIATION



SST/ROYAL SWEDISH ACADEMY OF SCIENCES

eclipse of August 19, 1887. Brown worried that customs officers would mistake the oblong box containing her telescope for something suspicious — perhaps even dynamite! After a long and exciting journey, though, clouds obscured the eclipse, allowing only a brief glimpse of the Sun's corona.

Caught in the Tropics recounted her journey with L. to the West Indies to observe the eclipse of December 22, 1889. Traveling on the Royal Mail Ship Tagus, Brown suffered from seasickness, but her first view of the Southern Cross thrilled her. She spent part of her time making color sketches of flowers, and her book recorded her impressions of the region's climate, environment, and people.

Observing the eclipse from a tower at Princes Town, Trinidad, she saw the clouds part to reveal the corona and a rosy light, though without long streamers or prominences, as were often viewed during eclipses.

When the LAS experienced serious difficulties in the late 1880s, Brown took an active role, along with E. Walter Maunder and others, in founding the British Astronomical Association (BAA), which, like the LAS, welcomed women members. Brown became director of the new group's solar section, and helped with divisions devoted to the Moon, variable stars, and star colors.

Her first program report in the *Journal of the British Astronomical Association* offered encouragement to women. "For ladies, many of whom have ample time at their disposal, and who are often skilful in the use of the pencil, this branch of observational Astronomy ought to have a special attraction," she wrote. "The Sun is always at hand. No exposure to the night air is involved, nor is there any need for a costly array of instruments."

She instructed beginning solar observers on how to make scientifically valuable observations. And she offered the following advice to those undertaking the demanding study of sunspots: "In the first place, if you would work to any purpose, expect at the outset, beyond the pleasure of being at work, few definite results; look for no great or stirring discoveries; be prepared for long periods when there will be little or nothing to record; but persevere."

Brown worked with Maunder and other astronomers around the world to gather observations from BAA members to address specific questions, such as whether faculae (bright regions on the Sun's surface) both precede and follow the birth of sunspots in a particular area. Astronomer John S. Townsend used her findings to propose that the reason many sunspot groups appear to grow on the Sun's eastern limb (edge) and decay as they near the western limb is because most groups do not live more than two weeks.

Between 1891 and 1899, Brown wrote seven major annual reports of the solar section, published in the Association's *Memoirs*. Each report presented a daily calendar of sunspot groups and their faculae, a sunspot ledger with detailed observations of each group, and her own exquisite drawings of sunspot groups, as well as drawings by others.

She also developed a system for classifying sunspots based on their shape, including pairs, clusters, trains, streams, zigzags, ellipticals, verticals, and dots. According to Larsen, Brown's system had elements in common with what eventually became the official system. "I think she should be recognized for her contributions as one of the many people in this road to try to figure out what are the different types, how are they related to the growth and decay of a sunspot group, and then ultimately, the physics," she says.

Although she receives little recognition for her contributions today, at the time Brown was well known by her colleagues. She belonged to astronomy societies in several countries, and in 1892, she was proposed for Fellowship in the Royal Astronomical Society, Britain's most prestigious astronomy group. She didn't receive the required three-fourths of the votes needed to gain election, though. (Between 1835 and 1916, the society bestowed honorary membership upon women who had made monumental contributions, although it didn't elect the first woman Fellow until 1916.)

For the most part, Brown lived a quiet country life with Jemima. A devout Quaker, she regularly attended the small Meeting in Cirencester. At the same time, she traveled widely — to Canada, the United States, Spain, and other countries — and attended the LAS meetings in Liverpool and the BAA meetings in London.

Brown died on March 5, 1899, after a week of bronchitis and as she was planning her fourth eclipse journey, to the western Mediterranean in May 1900. A dedicated scientist to the end, she completed the rainfall record for February 1899 during her final illness.

Her family and friends paid tribute to her gentle spirit, her perseverance, and her extraordinary contributions. Jemima Brown's touching tribute in the *Friends' Quarterly Examiner* emphasized her sister's quiet and unassuming character; few people in their town knew of her scientific eminence. She was buried in the cemetery of the Friends' Meeting House in Cirencester. She bequeathed her astronomical observatory and its contents, along with £1,000, to the BAA.

Through her intelligence, dedication, and creativity, Brown improved our understanding of the Sun. Equally important, her story is a shining example of the power of encouragement, from her father's nurturing of her early love of science to her passion for engaging others with astronomy.

Maria Chiara is a freelance writer in Evanston, Illinois.

Resources

Books

In Pursuit of a Shadow, by A Lady Astronomer (Elizabeth Brown), 1887

The Enigma of Sunspots. A story of discovery and scientific revolution, by Judit Brody, 2002

Women in Early British and Irish Astronomy: Stars and Satellites, by Mary Brück, 2009

Internet

Elizabeth Brown (1830-1899), solar astronomer
http://articles.adsabs.harvard.edu//full/1998JBAA..108..193C/0000193.000.html

In Memoriam. Elizabeth Brown. F.R.Met.Soc.
http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1899JBAA....9..214.

by Damond Benningfield and Rebecca Johnson

Pounding Out Two Small Moons

Simulations show Phobos, Deimos may be last survivors of a large family of Mars satellites

Earth's Moon most likely formed as the result of a "big whack" — a collision between the young Earth and another planet. The impact blasted debris into orbit around Earth, which quickly coalesced to form the Moon.

The moons of Pluto appear to have formed in the same way. And some recent research says the moons of Mars did, too.

Phobos and Deimos are small, oblong chunks of rock. Phobos has an average diameter of about 14 miles (22 km), and orbits about 3,700 miles (6,000 km) above the Martian surface. Deimos is roughly half as wide as Phobos, and more than three times farther from Mars.

The leading theory has been that Phobos and Deimos were asteroids that passed close to Mars, allowing the planet's gravity to lock them into orbit. But not all astronomers agreed with that explanation. The composition of the moons didn't seem quite right, for example. So the idea that they were born in a big whack has gained support in recent years.

It gained even more support from two studies published in July.

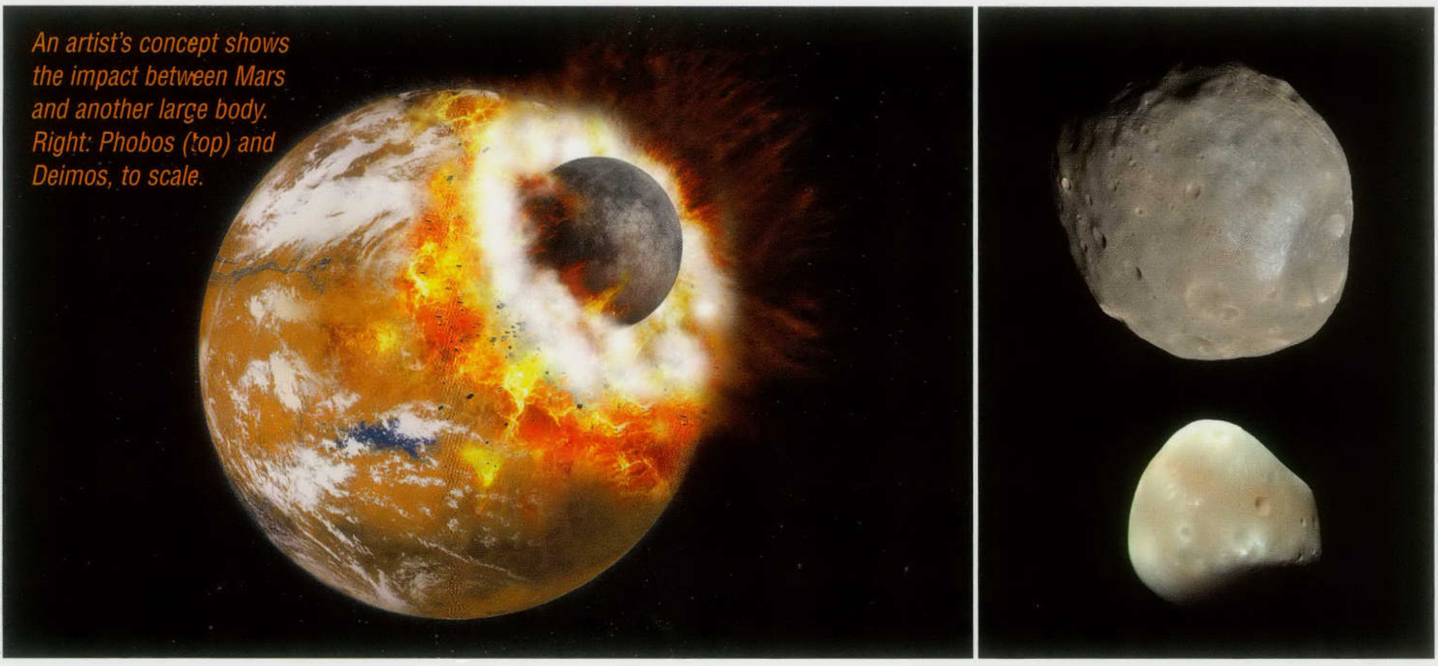
The first, by researchers in France, concluded that the composition of the surfaces of Phobos and Deimos is unlike the surfaces of the asteroids, suggesting that the two bodies are not captured asteroids. Instead, the study determined that they most likely formed from small grains of dust at the outer edge of a cloud of debris generated by the impact between Mars and another body. The dusty profile also would explain the low density of both moons, the researchers say.

The second study, by researchers from Europe and Japan, simulated a possible impact. The calculations showed that a body about one-third the size of Mars collided with the planet when it was 100 million to 800 million years old. The impact spewed molten rock, bits of dust, and hot gas into orbit around Mars, forming a wide, thin disk.

According to the simulations, molten rock close to Mars coalesced to form a moon 1,000 times the mass of Phobos, the larger of the two current moons. Over a few thousand years, gravitational interactions caused the remaining material to coalesce to form roughly 10 smaller moons close to Mars. Phobos and Deimos formed farther from the planet, where the disk consisted of small grains of dust.

Within a few million years, gravity pulled the closer moons back down. The impact of the biggest moon could have created the giant basin that covers much of the planet's modern-day northern hemisphere, according to the research.

Phobos and Deimos were the only survivors of this violent process. And Phobos has been spiraling closer to Mars ever since. Within 50 million years or so, it could slam into Mars as well, leaving the Red Planet with a single tiny moon. **DB**



An artist's concept shows the impact between Mars and another large body. Right: Phobos (top) and Deimos, to scale.

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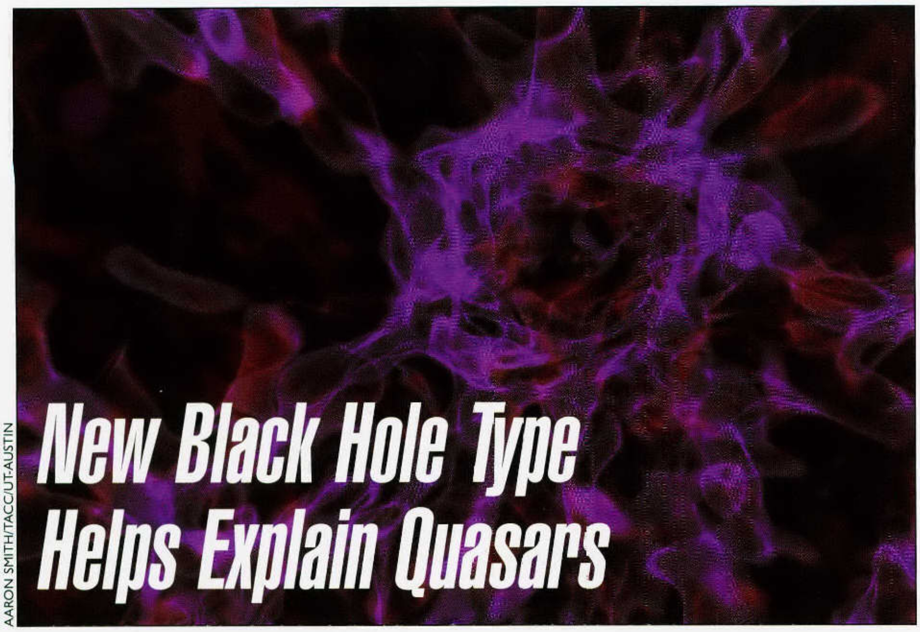
NASA/JPL/UNIVERSITY OF ARIZONA

New Black Hole Type Helps Explain Quasars



AARON SMITH/TACC/UT-AUSTIN

A simulation shows the environment in which primordial gas collapses to form a black hole. Gas flows along filaments of dark matter, with the first galaxies forming at the intersections of filaments.

Astronomers have discovered evidence for a type of black hole, predicted more than a decade ago, that may power quasars, some of the most powerful cosmic beacons in the early universe.

A quasar is powered by a disk of superhot gas that is spiraling into a supermassive black hole at a galaxy's center. Most quasars are billions of light-years from Earth, which means we see them as they looked when the universe was much younger. However, several problems should have prevented their formation early on.

In today's galaxies, supermassive black holes probably form by accretion: A massive star collapses, creating a "seed" black hole roughly 100 times as massive as the Sun. It grows by pulling in surrounding gas, and possibly by merging with other seed black holes.

Not so for quasars. They contained the first generation of stars, which could collapse to form stellar-mass black holes but could not work as quasar seeds because there was no surrounding gas for them to feed on. Winds from newly formed stars should have blown it away.

In 2003, Volker Bromm of The University of Texas at Austin and Avi Loeb of Harvard University devised a method to get an early galaxy to form a seed black hole, later dubbed "direct collapse."

Begin with a cloud of hydrogen and helium, suffused in a sea of ultraviolet radiation, Bromm explained. "You crunch this cloud in the gravitational field of a dark-matter halo. Normally, the cloud would be able to cool and fragment to form stars. However, the ultraviolet photons keep the gas hot, thus suppressing any star formation. These are the desired, near-miraculous conditions: collapse without fragmentation. As the gas gets more and more compact, eventually you have the conditions for a massive black hole."

Bromm, Loeb, and Texas' Aaron Smith put the theory to the test on CR7, a galaxy discovered at 1 billion years after the Big Bang by Hubble Space Telescope. Follow-up observations had discovered that CR7 is extremely hot, lacks heavy chemical elements, and has some other unusual features. The combination meant CR7 could either be a cluster of primordial stars or a supermassive black hole likely formed by direct collapse.

Smith ran supercomputer simulations for both scenarios. The star cluster scenario "spectacularly failed," Smith said, while the direct collapse black hole model performed well. Taken together with the recent discovery of two additional direct-collapse black hole candidates by Chandra X-Ray Observatory, this means that scientists are converging on the direct-collapse model to explain supermassive black holes in the early universe, Smith said. **RJ**

Warming a Cool Planet

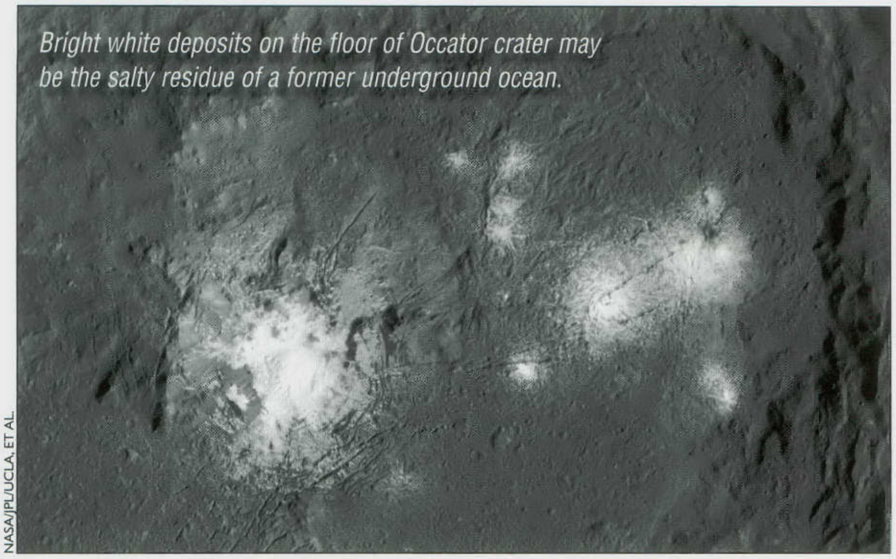
When it comes to the greenhouse effect, timing is everything. The current warming of our planet is forecast to have dire effects on life. A greenhouse effect when Earth was young, however, may have been a boon for life.

When Earth was born, the Sun was fainter and cooler than it is today. That means Earth wouldn't have received enough energy for liquid water to exist on its surface. Instead, any water would have been frozen solid, making it more difficult for life to take hold. Yet the geologic record of that early era suggests liquid water did exist on the surface of the young Earth.

A recent study by researchers at the Southwest Research Insitute proposed a possible solution to the problem: a steady bombardment of asteroids.

By looking at the craters on the Moon and Mercury, we know that the worlds of the inner solar system were pounded by asteroids for several hundred million years. On Earth, those impacts vaporized the asteroids, spewing hot gas and rock into the atmosphere. They also created pools of molten rock on the surface.

The recent research says that the bubbling rock released large amounts of carbon dioxide and other greenhouse gases into the developing atmosphere. That trapped more of the weak solar energy, warming the planet enough to melt the ice and create lakes and oceans. The impacts also delivered much of the chemistry of life, the study notes, perhaps helping to trigger the development of the first microscopic organisms on Earth billions of years ago. **DB**



Bright white deposits on the floor of Occator crater may be the salty residue of a former underground ocean.

NASA/JPL/UCLA, ET AL.

Ceres' Ice Vaporizes

Although there's less ice below the surface of Ceres than expected, some ice has recently oozed to the surface, leaving bright white mineral deposits inside a large crater, according to two recent studies based on observations by Dawn, a spacecraft that has orbited the largest member of the asteroid belt since May 2015.

One study examined the composition and contours of white deposits in Occator crater, which formed about 80 million years ago. The white material appears to have bubbled to the surface through networks of cracks in the crater floor.

Mission scientists say their results suggest the salty minerals reached the surface several million years ago, perhaps when water from an underground ocean bubbled up to the surface. Exposed to the vacuum of space, the water evaporated, leaving the salty residue.

A second study, on the other hand, found that there is less ice beneath Ceres' crust than expected. The density and shape of Ceres, which is less than 600 miles (1,000 km) in diameter, had suggested that a thick layer of ice was just below the surface, with the possibility of a global ocean of liquid water.

The new study, however, examined the contours of the dwarf planet's largest craters. It found that, regardless of age, most of the craters are quite deep. A subsurface layer of ice and water should help push the crater floors upward, making the older ones much shallower than the younger ones. The consistent depth, however, suggests that the subsurface layer can contain no more than 40 percent water and ice, with rock accounting for most of the material in that layer.

A few craters are shallower than the others, though, which could mean that there are ice-rich pockets below the surface, between regions with heavier concentrations of rock. **DB**

Death from Afar

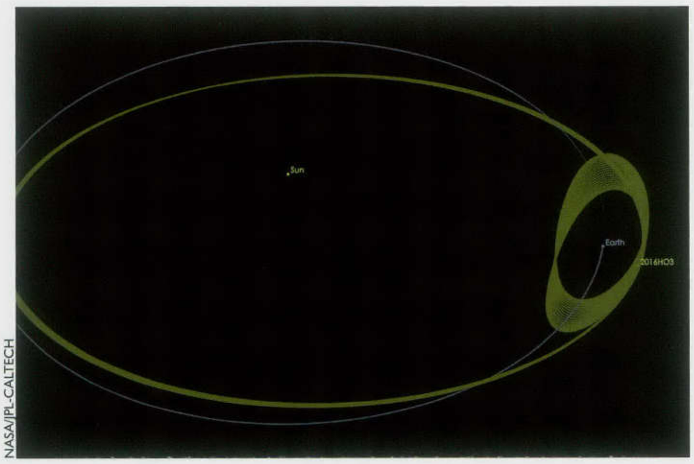
Radiation from nearby supernovae may have had lasting effects on life on Earth

Exploding stars may have pelted our planet with enough radiation to boost cancer rates, increase genetic mutations, and alter the climate, according to a recent study by researchers in the United States and Europe.

Studies published earlier this year, based primarily on the presence of a radioactive form of iron in ocean sediments, reported that two or more supernovae may have exploded within 300 light-years of Earth. One explosion (or group of explosions) took place 1.7 million to 3.2 million years ago, while the second was about five million years earlier. Debris from the blasts sprinkled into Earth's atmosphere and down to the surface.

A follow-up study looked at the possible effects on Earth's life. It found that cosmic rays, which are heavy particles generated in the blasts, may have created showers of particles that bombarded the surface. These particles may have tripled the background radiation dosage, exposing every living creature on the surface and in shallow waters to the equivalent of one CT scan per year, with the radiation bath continuing for millennia.

The researchers say that the radiation also could have increased cloud cover and storm activity on Earth, altering global temperatures. The combination of increased radiation exposure and climate change could have contributed to die-offs found in the geologic record, the researchers suggest.



NASA/JPL-CALTECH

The orbits of Earth (white) and 2016 HO3 (yellow) around the Sun.

Obi Wan Was Right: That's No Moon

Recent reports that Earth has gained a permanent second moon are misleading. A small asteroid called 2016 HO3 that is gravitationally bound to our planet will break away in several centuries, as others have done.

Paul Chodas, manager of NASA's Center for Near-Earth Object Studies, said in a statement that HO3 has been a "qausi-satellite" of Earth for almost a century. It spends about half of its time orbiting the Sun ahead of Earth, and half behind, never coming closer than 38 times the Earth-Moon distance. Its orbit is tilted to Earth's, so it moves from above Earth to below and back again. "In effect, this small asteroid is caught in a little dance with Earth," Chodas said.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Clouds of gas and dust, massive young stars, and the 'failed stars' known as brown dwarfs fill this image of the Orion Nebula, one of the most detailed ever snapped of the stellar nursery 1,350 light-years from Earth. Taken in infrared light by the European Southern Observatory's Very Large Telescope, the image also shows giant cavities carved in the nebula by hot, young stars, and stellar embryos still wrapped in cocoons of dust.