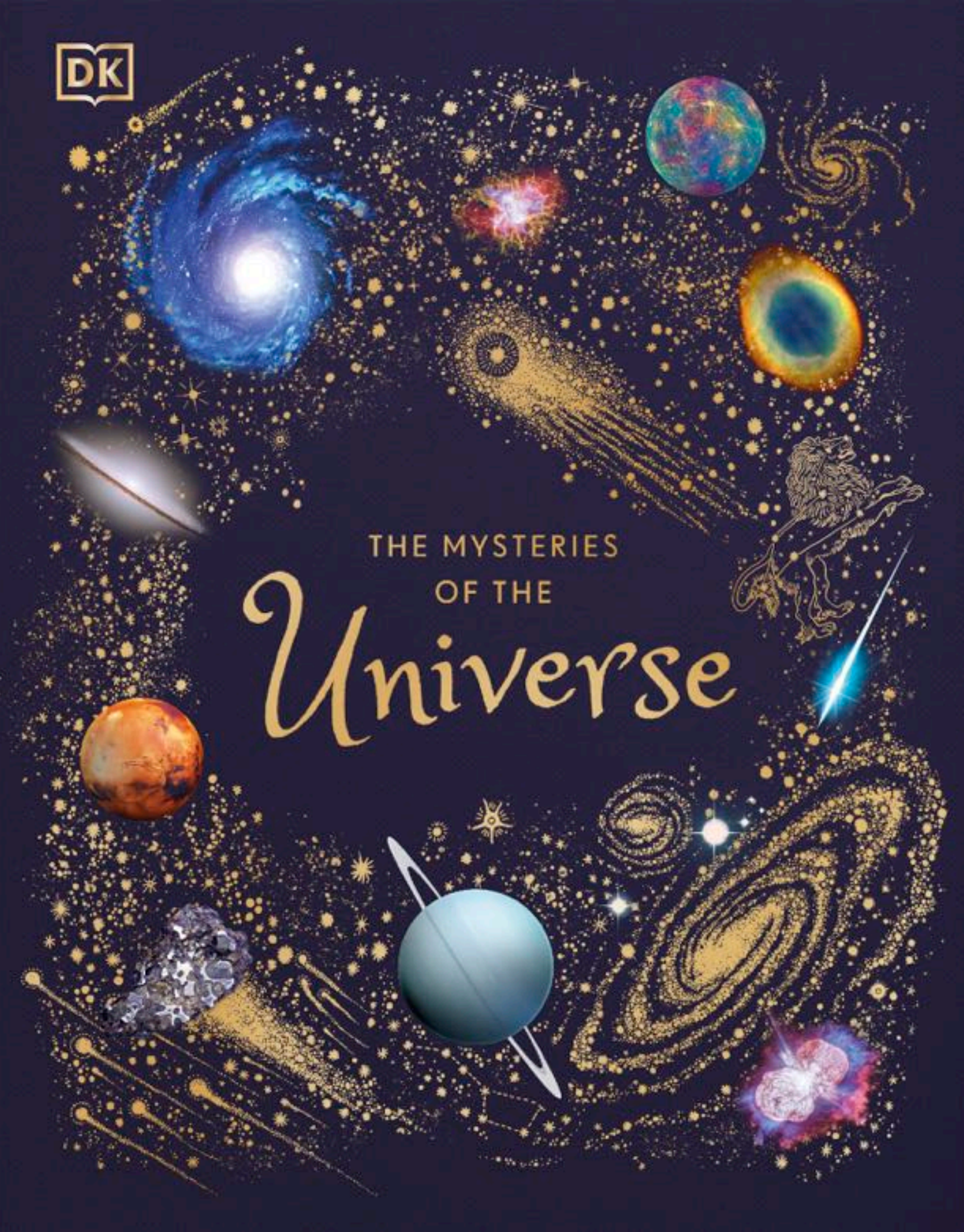

DK
THE MYSTERIES
OF THE
Universe

# THE MYSTERIES OF THE Universe

Written by Will Gater

Illustrated by Angela Rizza
and Daniel Long

DK

# Introduction

Are you ready to go on an adventure? As you turn the pages of this book you'll be following in the footsteps of countless adventurers, scientists, and stargazers who have wondered at the great mysteries of the universe. The journey will begin on our home planet, Earth, a marvel all in itself, and continue farther and farther into space, to the planets of our solar system and out to the stars and galaxies beyond. As you meet some of the most extraordinary objects in the cosmos, you'll learn all about what they are and how astronomers study them, and you'll also see that there's a lot we still don't understand—many mysteries are yet to be solved!
Now, let's get going!

Will Gater
Author

**Note from the publisher**

Remember: never, ever look directly at the sun—
it is so bright that it will damage your eyes!

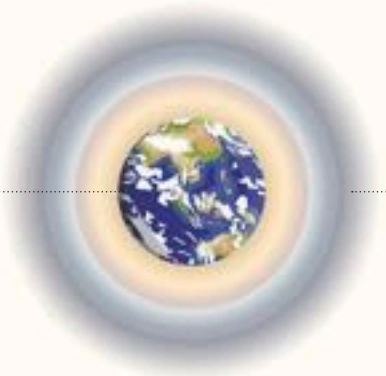
# Contents

# Earth's atmosphere

Our atmosphere might only be a thin veil of gas that clings to our planet, but it allows us to live here, and it is where many beautiful celestial sights, such as meteors and auroras, are created.

When we look up on a clear day, the sky glows a vibrant shade of blue. This is because the gases in the air scatter the bluer colors in the sunlight. When night falls, we can see another effect of the atmosphere: the gentle twinkling of the stars. This flickering happens because the moving air above us briefly distorts the path starlight takes to reach our eyes.

Our atmosphere is mostly made up of nitrogen, with smaller amounts of other gases such as oxygen and carbon dioxide.




Noctilucent, or "night shining," clouds are only visible at twilight.

# The night sky

Humans first turned telescopes toward the night sky around 400 years ago.

This dazzling view is from the Atacama Desert in Chile.

Every evening, as darkness falls and the sky turns from deep blue to inky black, the wider cosmos comes into view. Glittering stars fill the sky to form a sparkling backdrop for the planets that sail above our heads. Occasionally, a meteor zips across the scene, while night after night the moon's silvery face slowly cycles through its phases.

Today, astronomers use powerful telescopes to peer deep into space, enabling us to explore the very distant universe. Here, there are billions of galaxies, each full of countless stars. Perhaps in one of them there's someone else looking up, marveling at the magic of their own twinkling night sky!

# Meteors

Have you ever spotted a shooting star? These fleeting streaks of light are formed when a tiny piece of space dust—usually about the size of a grain of sand—hits our atmosphere. The flecks of dust themselves are strewn throughout the solar system, and when they collide with Earth some are traveling at speeds as fast as 150,000 miles (240,000 km) per hour.

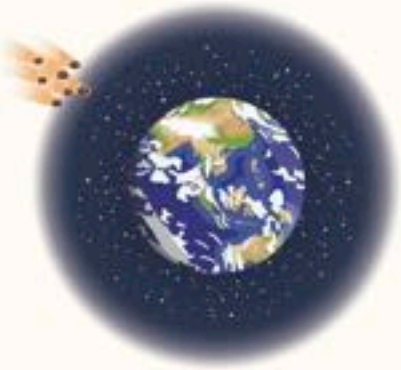
As the dust crashes into our atmosphere it squashes the air, causing the gas in front of it to heat up. In a split second, the dusty grain begins glowing and is quickly vaporized as it races across the sky—this is what we see as a shooting star, or to use its scientific name, a meteor.

Meteor showers–when meteors streak from the same point in the sky–occur when Earth passes through a trail of dust left behind by a comet or asteroid.

A bright meteor falling during the Geminid meteor shower, which occurs every December.

This meteorite was discovered in Chile's Atacama Desert.

# Meteorites



Sometimes a space rock is so big that if it hits Earth's atmosphere it can survive its fiery journey through our skies without being totally destroyed. When a chunk of cosmic debris lands on the ground, it is called a meteorite.

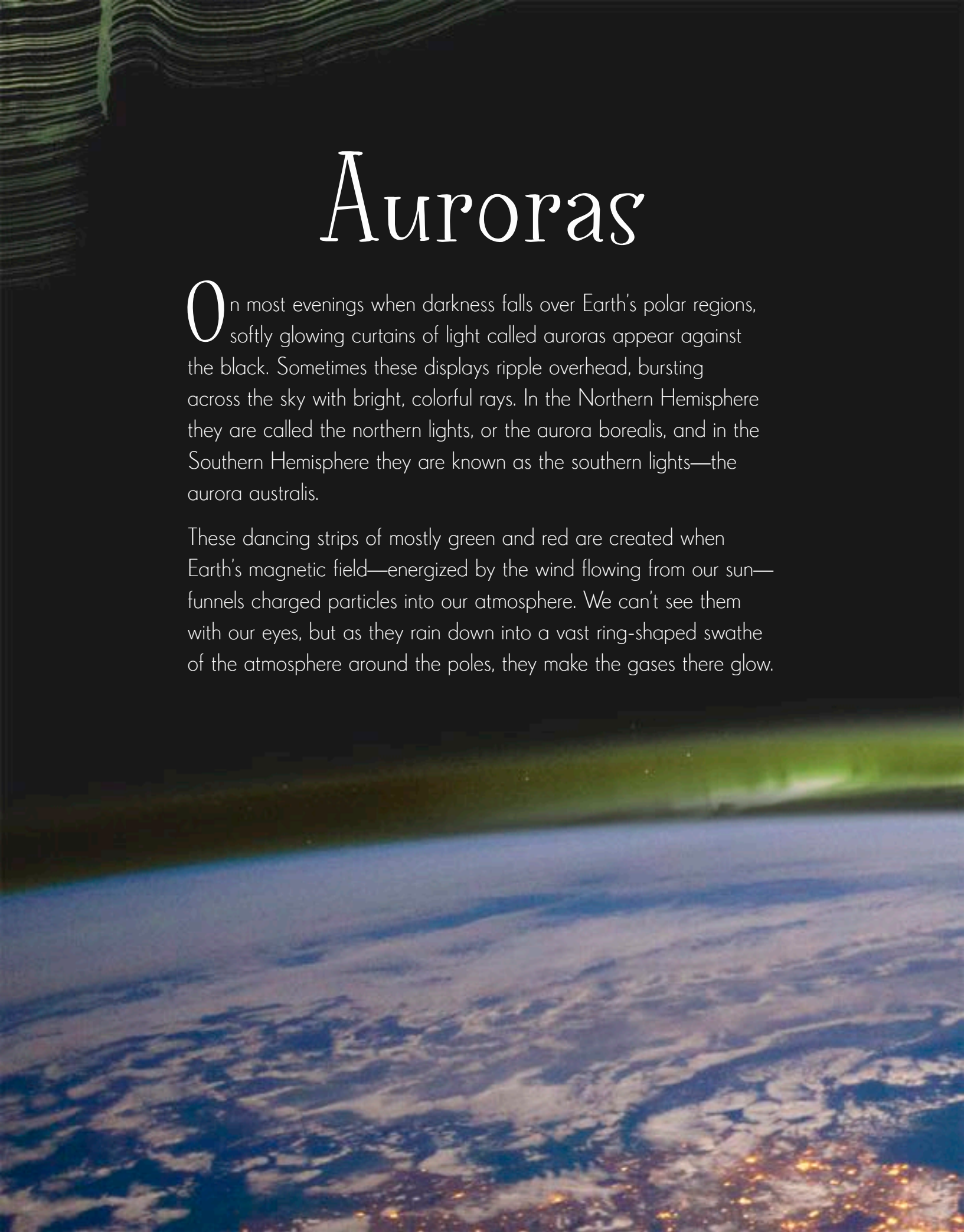
Meteorites come in many different forms. Some are stony, while others are made mostly of metals, such as iron and nickel. Scientists regularly scour deserts and other remote areas, such as Antarctica, looking for meteorites. This is because studying them tells us about what distant solar-system objects are made of, and can reveal the hidden history of the planets.

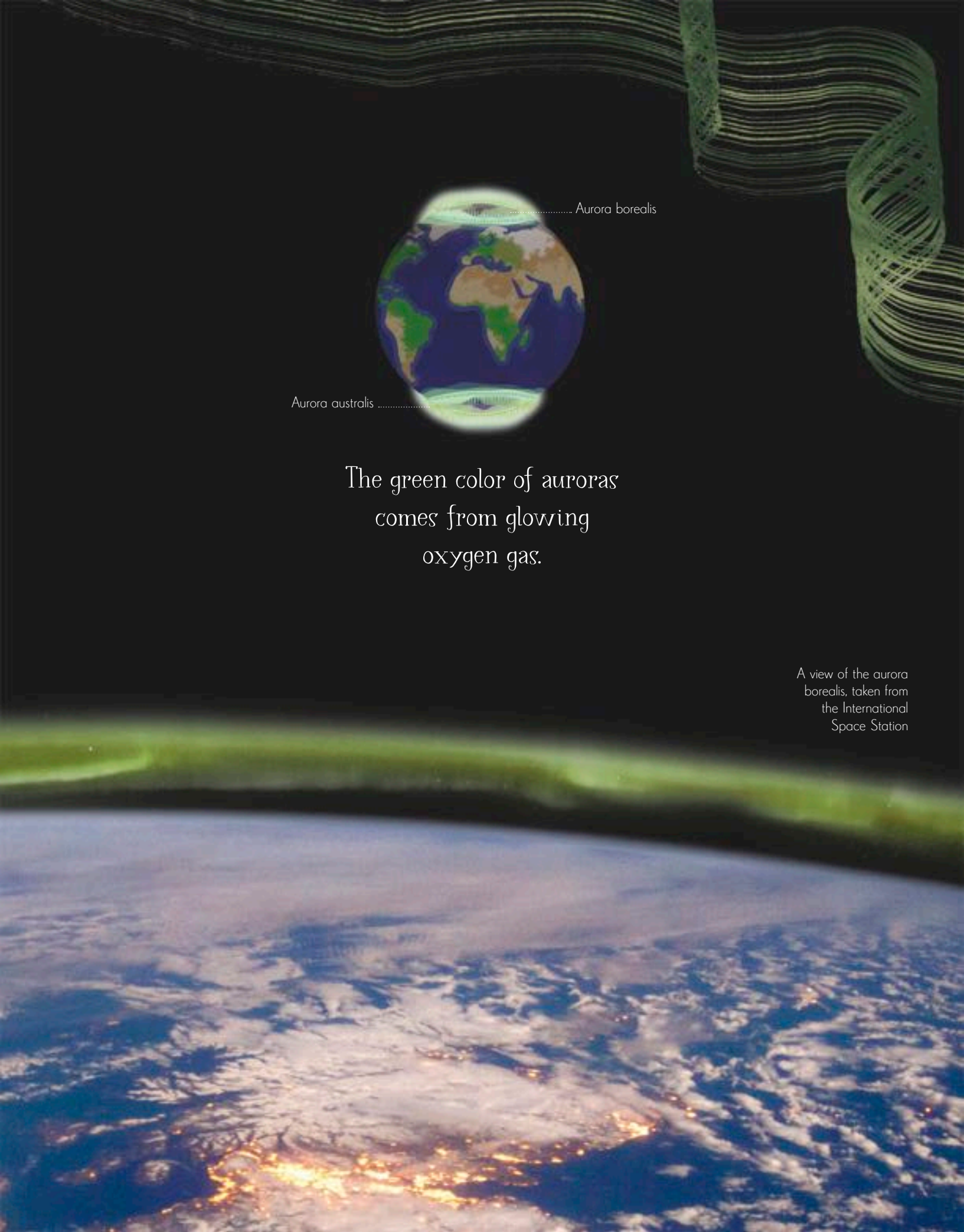
Some meteorites are actually pieces of the moon and Mars.

# Auroras

On most evenings when darkness falls over Earth's polar regions, softly glowing curtains of light called auroras appear against the black. Sometimes these displays ripple overhead, bursting across the sky with bright, colorful rays. In the Northern Hemisphere they are called the northern lights, or the aurora borealis, and in the Southern Hemisphere they are known as the southern lights—the aurora australis.

These dancing strips of mostly green and red are created when Earth's magnetic field—energized by the wind flowing from our sun—funnels charged particles into our atmosphere. We can't see them with our eyes, but as they rain down into a vast ring-shaped swathe of the atmosphere around the poles, they make the gases there glow.






The green color of auroras comes from glowing oxygen gas.

A view of the aurora borealis, taken from the International Space Station

The constellation Orion is named after a hunter in Greek mythology.

# Constellations

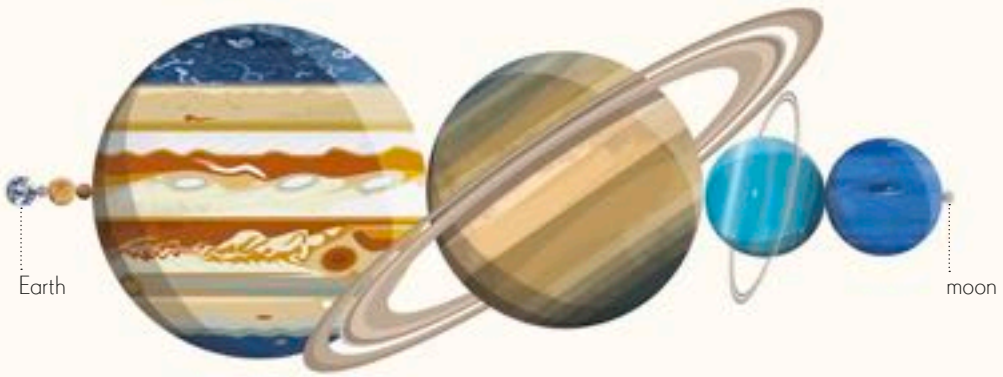
Have you ever spotted a familiar outline or shape in the sparkling stars of the night sky? You're not alone. For thousands of years, sky watchers from cultures all over the world have picked out patterns in the stars, called constellations. Today, the International Astronomical Union recognizes 88 constellations. These represent all kinds of objects and creatures, as well as mythical figures—(see pp. 200–203). Star shapes that aren't official constellations, such as the Big Dipper and the Summer Triangle, are called asterisms.

Most of the constellations that are visible in the night sky change with the seasons, as Earth moves around the sun. This means the stars we see in summer are different from those we see in winter.

This is the constellation Orion. Can you spot his belt?

# The moon

Gaze up at the moon on a clear night and you'll be looking at an object that has billions of years of history etched into its surface. Its cratered landscape tells the story of countless asteroid and comet impacts long ago in the lifetime of the solar system. But how did this ball of rock end up orbiting Earth? That's something that puzzles scientists even today. The most popular theory is that around 4.5 billion years ago, the young Earth collided with another world—the impact was so violent that this second world was destroyed, and huge amounts of hot, molten material were blasted into space. Eventually, the debris clumped together and cooled, and the moon was born.




When the moon is farthest from Earth, you could fit the seven other planets in the space between!

This image shows the moon crossing the sunlit side of our home planet.

# Phases of the moon


You have probably noticed that the moon looks as if it is always changing shape. Sometimes it looks like a banana, while other times it's round, like a dinner plate. Sometimes it is somewhere between the two. These changing shapes are known as the phases of the moon.

The phases happen because the moon is constantly moving around the Earth. This means the amount of its face that's lit up by sunlight changes night after night. The moon is spinning too, but we only ever see one side of it because it rotates on its axis in about the same amount of time as it takes to zoom around our planet!

The dividing line between the sunlit part and the dark part of the moon's face is known as the terminator.

Waning gibbous

Third quarter

Waning crescent

New moon

The moon rotates on its axis as it moves around the Earth.

A total lunar eclipse can reveal stars that
are usually hidden by the moon's glow.

# Lunar eclipse

Did you know that sometimes the moon turns a stunning shade of red? Well, it's not the moon itself that changes color, although it might look that way. It's all because of Earth's atmosphere and our planet's shadow.

Very occasionally, the Earth, the sun, and the moon are aligned in such a way that Earth casts a shadow over a full moon. When this happens, the moon's silvery white face gradually darkens, in what astronomers call a total lunar eclipse. Yet even in full shadow, the moon doesn't disappear from view. That's where Earth's atmosphere comes in! Our skies filter the sunlight passing through them, leaving only the redder colors to make it out into space. Not only that, but the atmosphere also bends that reddish glow into the gloom of our planet's shadow. The result: a copper-colored full moon hanging in the sky.

The full moon turns a beautiful red during a total lunar eclipse.

The light of earthshine takes about 1.3 seconds to travel from our planet to the moon.

# Earthshine

Everyone knows that the Earth doesn't shine... or does it? Take a look at a thin, crescent moon. You'd expect the rest of its round face to be hidden in darkness, since it is night on that part of its surface and there's no sunlight reaching there. But look carefully and you will see that the whole moon is faintly lit up. Believe it or not, our planet is responsible!

When the sun shines on Earth's clouds and oceans, they send some of that light back out into space in different directions. This earthshine can reach our neighbor, where it illuminates the nighttime lunar landscape with a faint glow. It's just like here on Earth when a bright moon casts its silvery light on the ground.

Earth's reflected light is brightest in the Northern Hemisphere's spring.

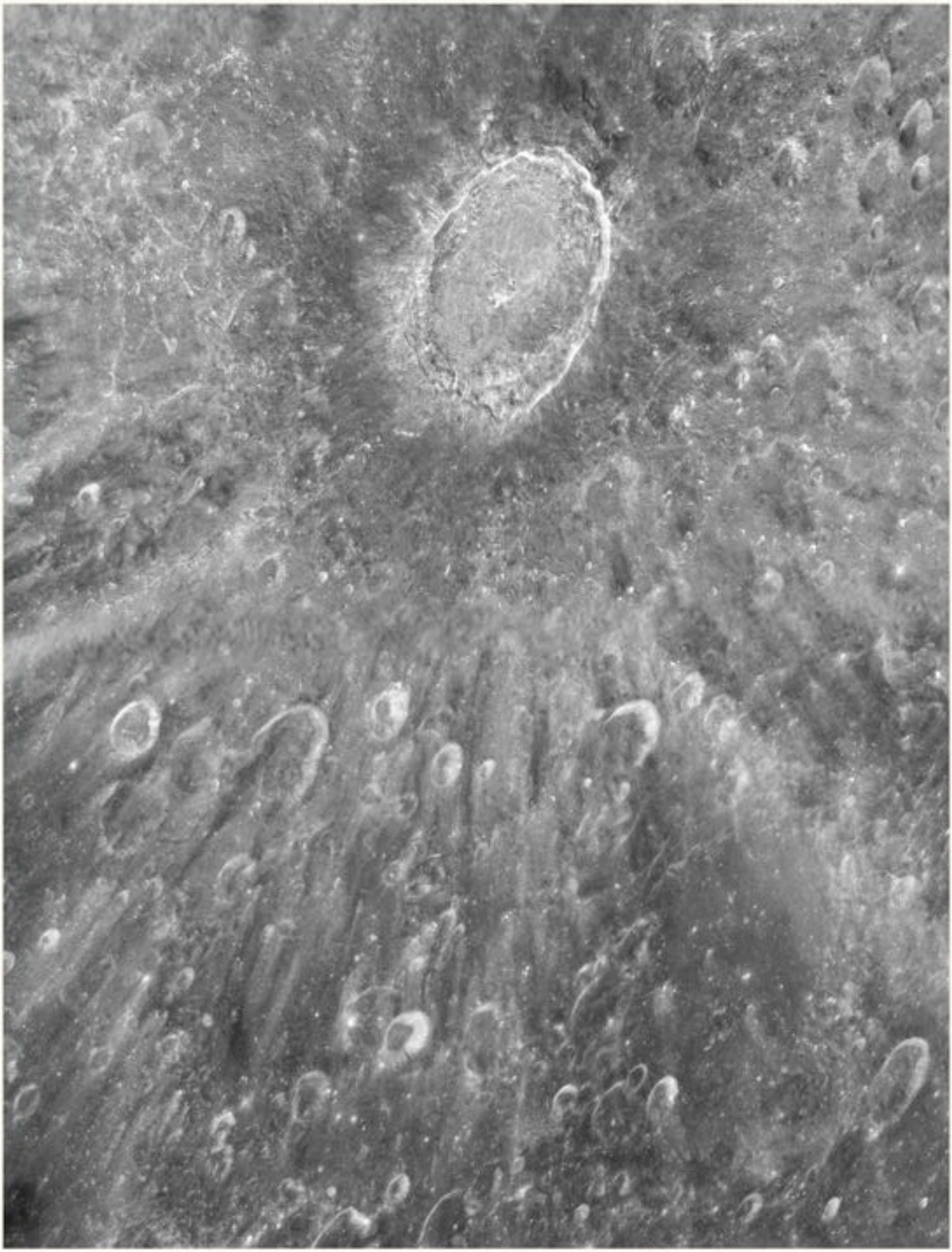
In 1651, an Italian astronomer, Giovanni Battista Riccioli, gave the "seas" their beautiful names.


# Lunar seas

If you had been looking up at the moon a few billion years ago, you would have witnessed one of the most spectacular sights ever to occur in the solar system. A hail of asteroids pounded into the moon, gouging out huge holes, called basins, in the surface.

Over time, these enormous scars became filled with molten rock seeping up from inside the moon. Eventually, this cooled and solidified to form vast, open plains—these are the dark-gray areas that we can see on the face of the moon today. Early astronomers thought these areas looked like giant pools of water, so they called them lunar *maria* (the Latin word for seas). This is quite a misleading name, since there aren't any watery waves lapping their shores. Instead, the moon's surface is covered in fine, powdered rock called regolith.

The lunar seas are darker and smoother than their cratered surroundings.



# Tycho

Tycho

When the first astronomers to use telescopes turned these newly invented instruments toward the moon, they were captivated by what they could see. Huge areas of its silvery-gray face were covered in enormous dish-shaped pits, creating a rugged and pockmarked landscape. Today, we know that these craters are the result of asteroids and comets crashing into the moon and gouging out great chunks of its surface.

One of the most impressive lunar craters is Tycho. When it was formed, the impact was so great that part of the moon's surface bounced back upward to create mountains in its center! With a small telescope, you can even see where debris shot away from Tycho as the asteroid crashed into the lunar rock—these are the bright streaks that extend out from the crater.

Tycho is so large that it could fit all of London within its walls.

Scientists think Tycho is about 100 million years old—it hasn't been damaged yet by other asteroid impacts.

# Moonwalking

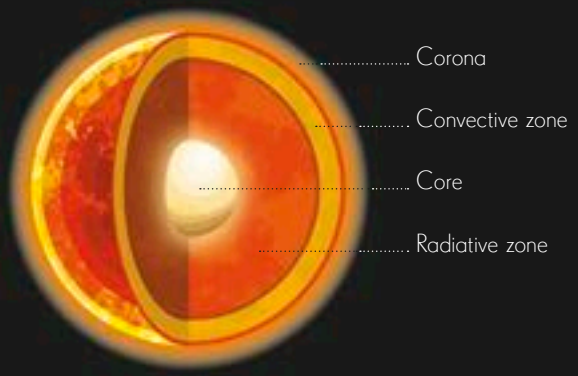
So far, only 12 people have walked on the moon's surface. The first was Neil Armstrong, in 1969.

Imagine what it must feel like to step out onto another world—a place where the sky is pitch black and where there is no air or clouds, so distant landscapes look crisp and clear. A place without trees or plants, where the ground all around is a dark-gray powder peppered with craggy rocks and boulders.

This is the scene that faced the astronauts who traveled to the surface of the moon on the Apollo missions of the late 1960s and early 1970s. As they took these extraordinary first steps, the moonwalkers snapped pictures, performed experiments, and on some missions even drove a specially built moon buggy. There is no wind or liquid water on the moon to disturb the landscape, so the astronauts' footprints are preserved in the lunar dust to this day.

Can you spot the astronauts' footprints?

# The sun

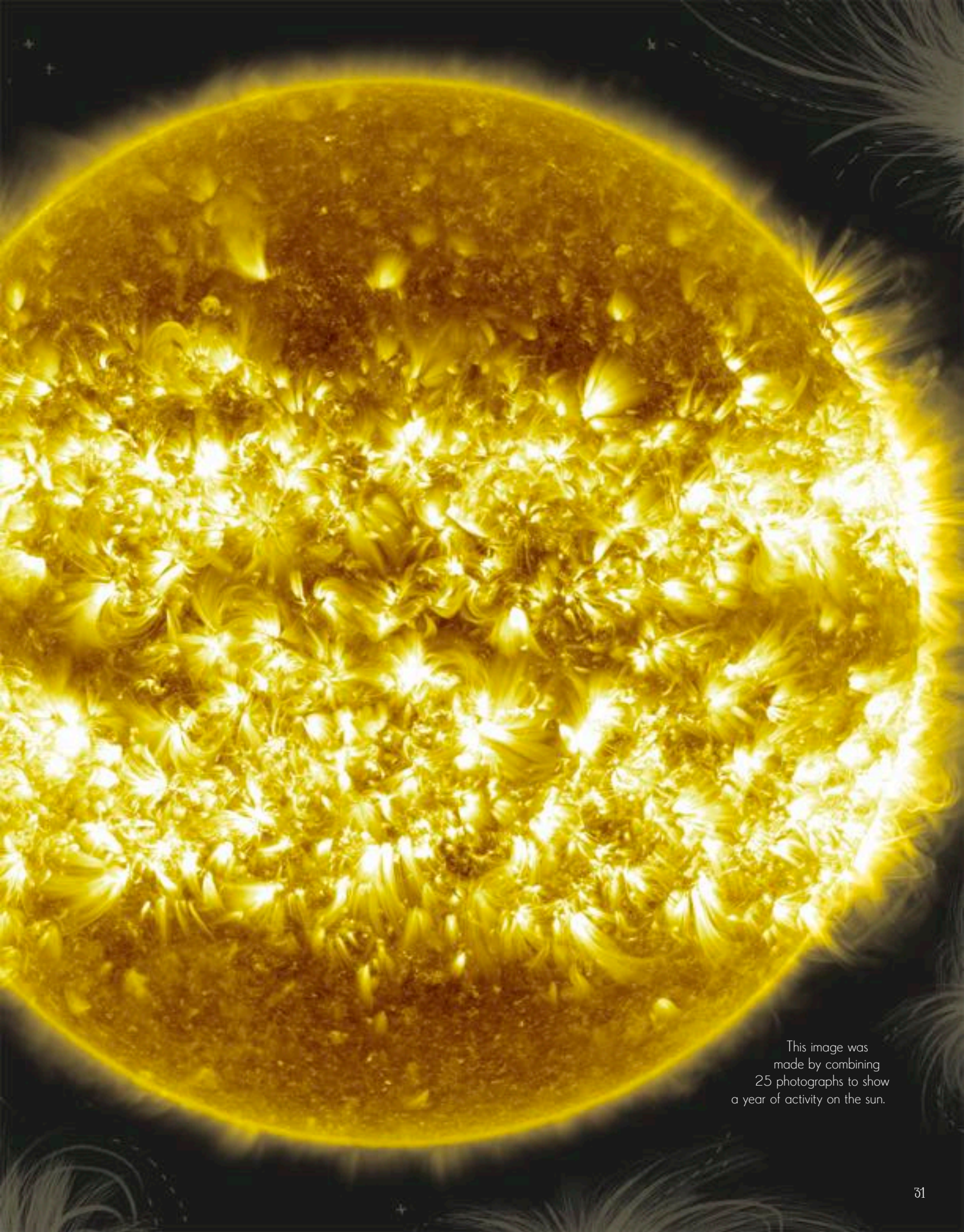



Did you know that the sun is a star, just like the countless points of light sparkling in the night sky? In fact, it is relatively small compared to some of the other stars in the Milky Way. But it's still the object our little planetary family—the solar system—whirls around, and its warmth and light make Earth a place where life can exist.

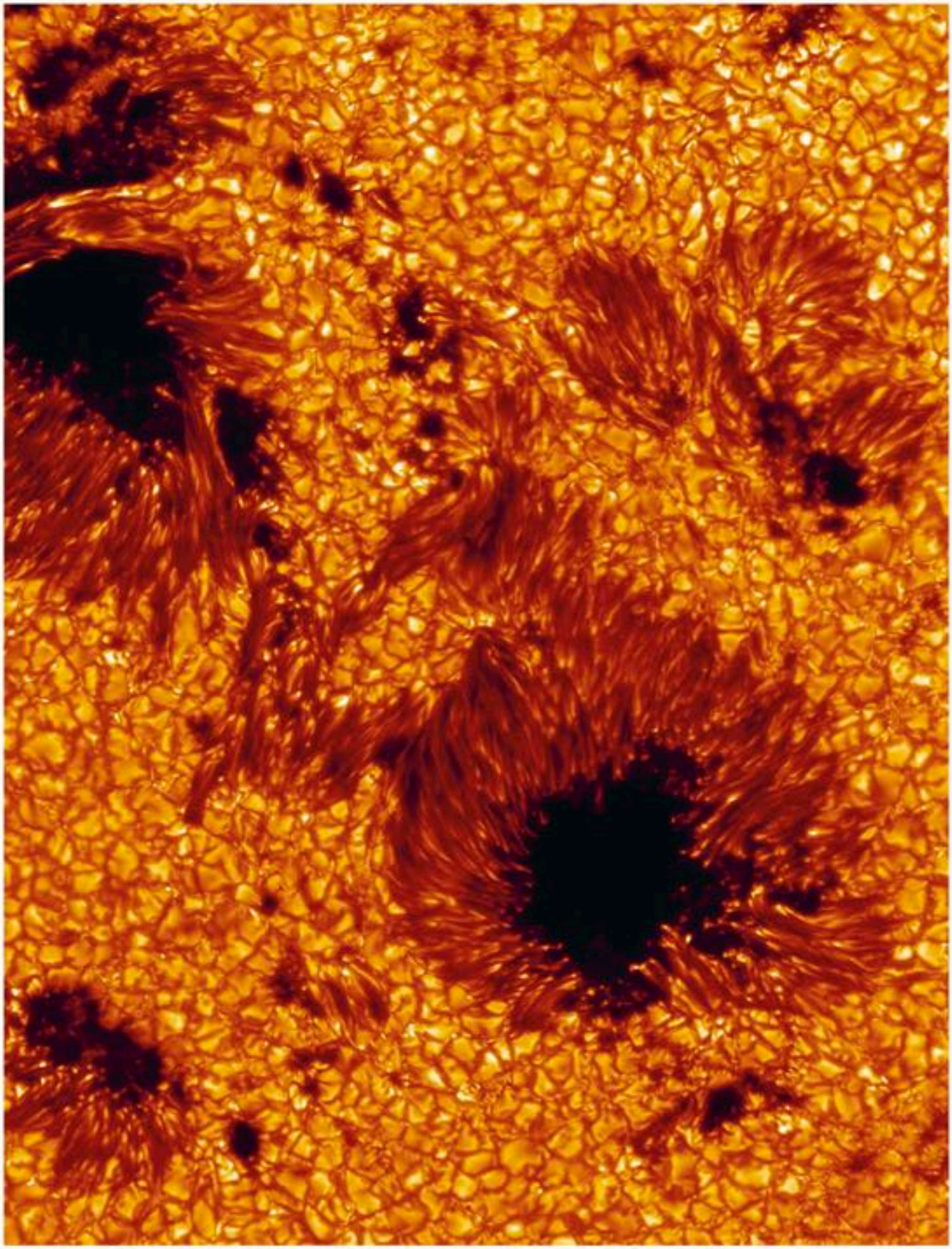
The sun's power comes from reactions unfolding deep within its core—here, superheated matter is fused, or joined together, under immense temperatures and pressures. This process releases energy, which works its way out from the center to create the blazing hot, glowing ball that travels across the sky.

Astronomers think the sun will live for about another 5 billion years.

Remember: never, ever look directly at the sun—it is so bright that it will damage your eyes!

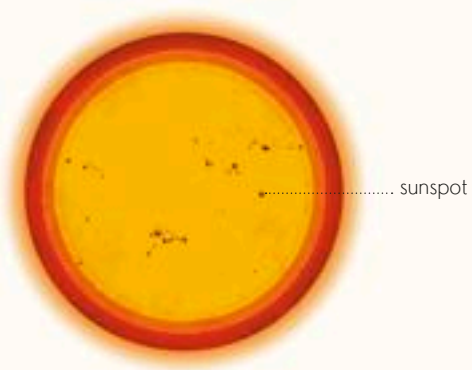


This image was made by combining 25 photographs to show a year of activity on the sun.



# Sunspots

A single sunspot can be bigger than the entire Earth!




The sun

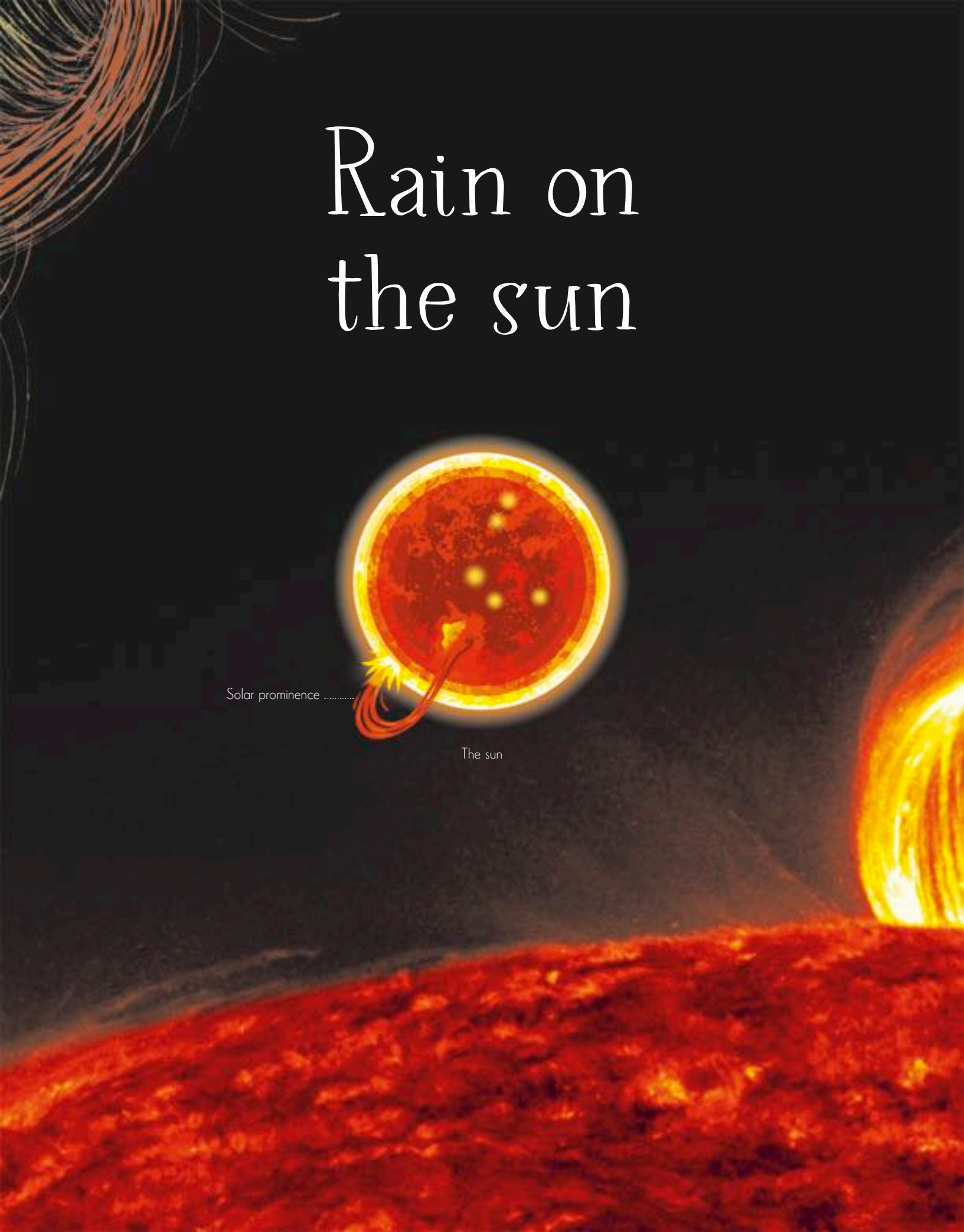
The surface of the sun is unlike any other place in the solar system. It has been bubbling and blazing away every second for billions of years, beaming with incredible amounts of heat and light.

Astronomers call the sun's surface the photosphere, and it has a temperature of about 9,752°F (5,400°C). Sometimes, magnetic fields emerging from inside the sun reduce the amount of heat reaching parts of the surface. This creates cooler, darker patches of the photosphere, which we call sunspots. Larger sunspots usually have two parts to them—a dark heart, called an umbra, and a lighter border known as a penumbra. Sunspots can last many months, or they can disappear in just a few days.

Sunspots sometimes appear in groups, like these, spotted by the Swedish Solar Telescope.

Remember, it's important to never look directly at the sun!

# Rain on the sun

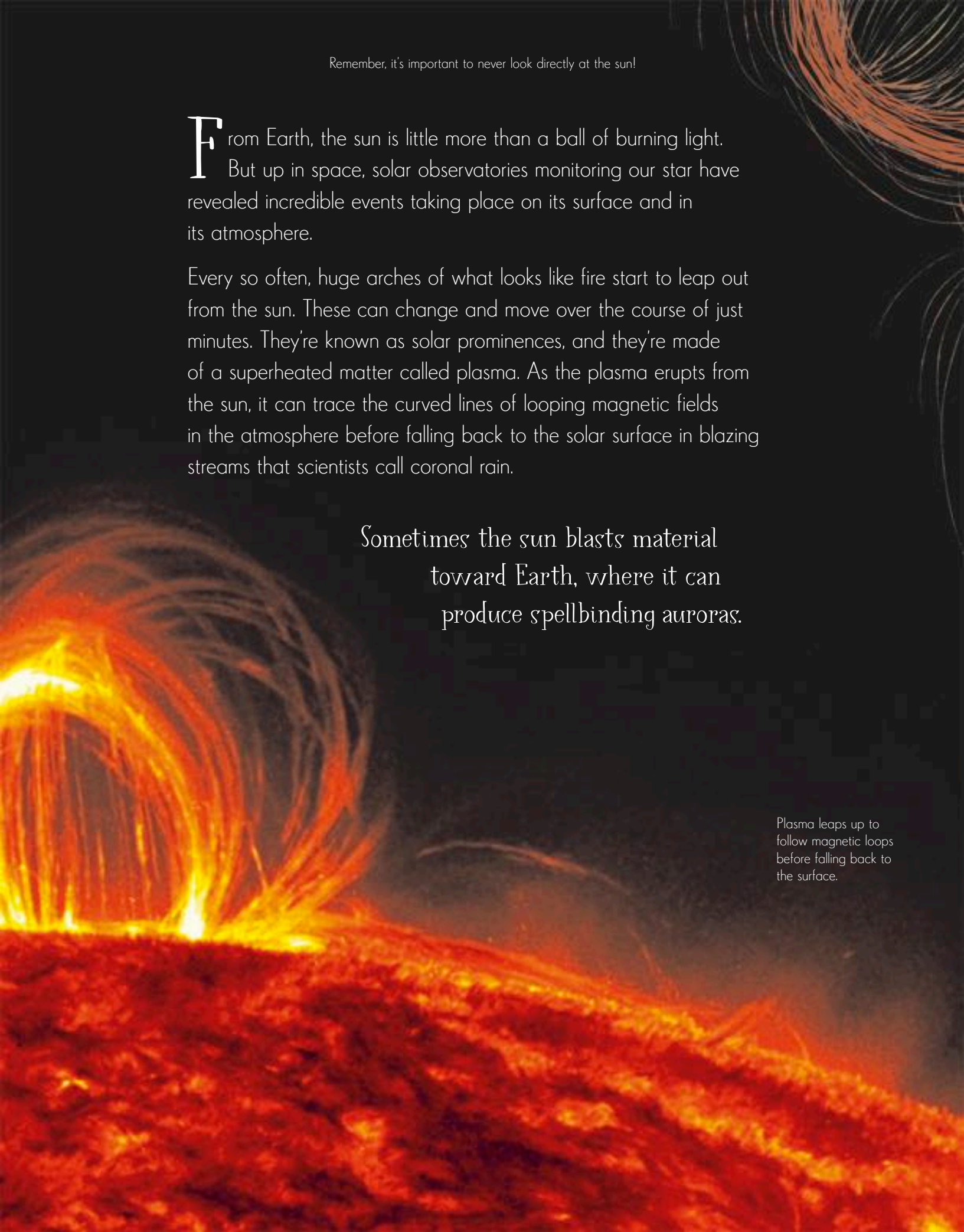


Remember, it's important to never look directly at the sun!

From Earth, the sun is little more than a ball of burning light. But up in space, solar observatories monitoring our star have revealed incredible events taking place on its surface and in its atmosphere.

Every so often, huge arches of what looks like fire start to leap out from the sun. These can change and move over the course of just minutes. They're known as solar prominences, and they're made of a superheated matter called plasma. As the plasma erupts from the sun, it can trace the curved lines of looping magnetic fields in the atmosphere before falling back to the solar surface in blazing streams that scientists call coronal rain.

Sometimes the sun blasts material toward Earth, where it can produce spellbinding auroras.



Plasma leaps up to follow magnetic loops before falling back to the surface.

# Total solar eclipse

The white wisps around the moon during a total solar eclipse are part of the sun's outer atmosphere, known as the corona.

Sometimes, the shadow of the moon sweeps across the globe of the Earth. When this happens, anyone standing where the darker, central part of this shadow falls will experience a total solar eclipse. A total solar eclipse usually happens at least once every couple of years.

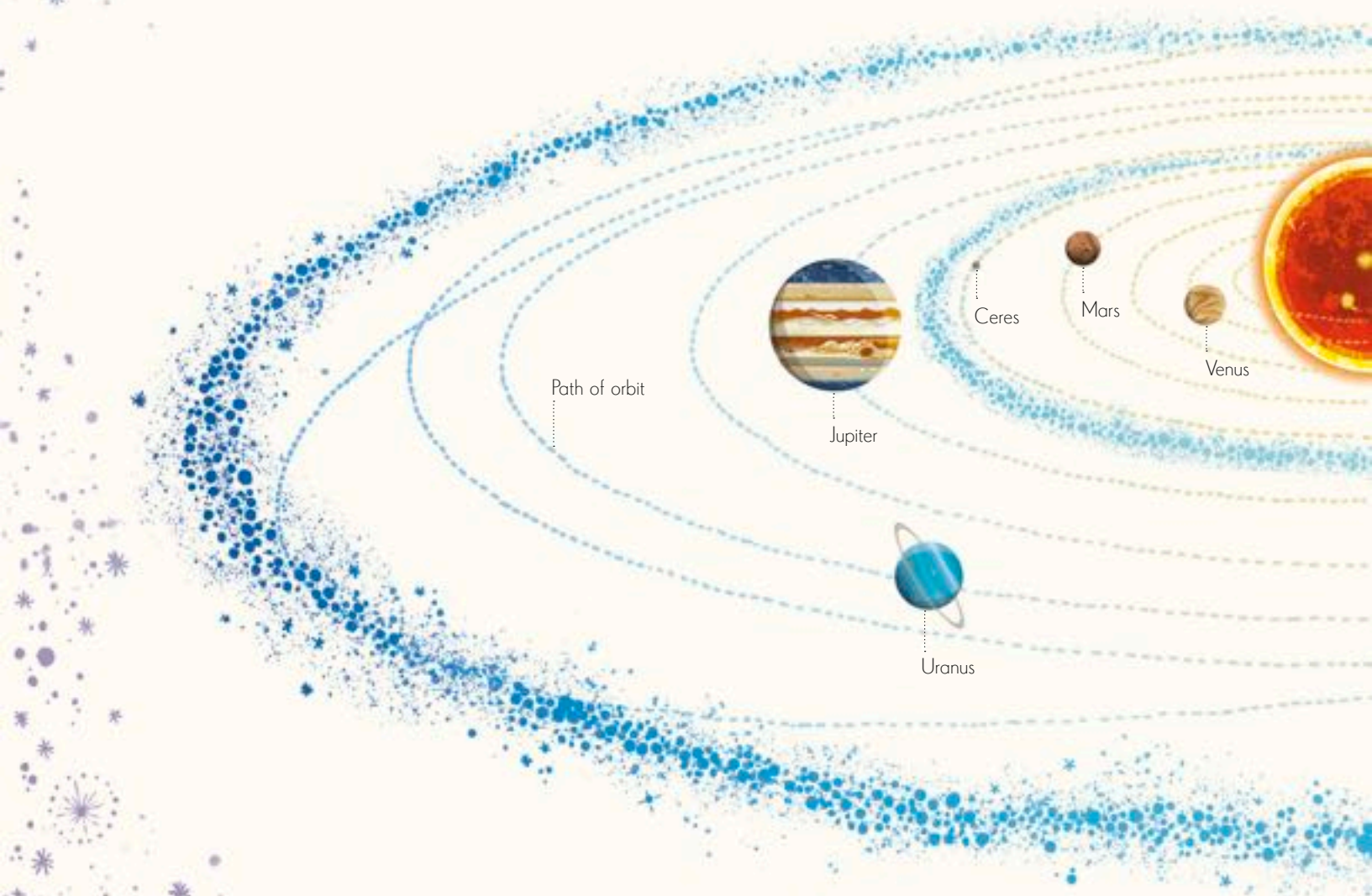
During these spine-tingling events, the daylight slowly begins to fade to twilight. The air cools, and animals often behave as if they're preparing for the evening. Soon after, a strange, silvery light falls on the landscape, and for a few moments everything gets dark, as the sun is entirely blocked by the black disk of the moon—this event is known as totality. As the core of the moon's shadow moves away, totality ends and the sun's light gradually returns.


Remember, it's important to never look directly at the sun!

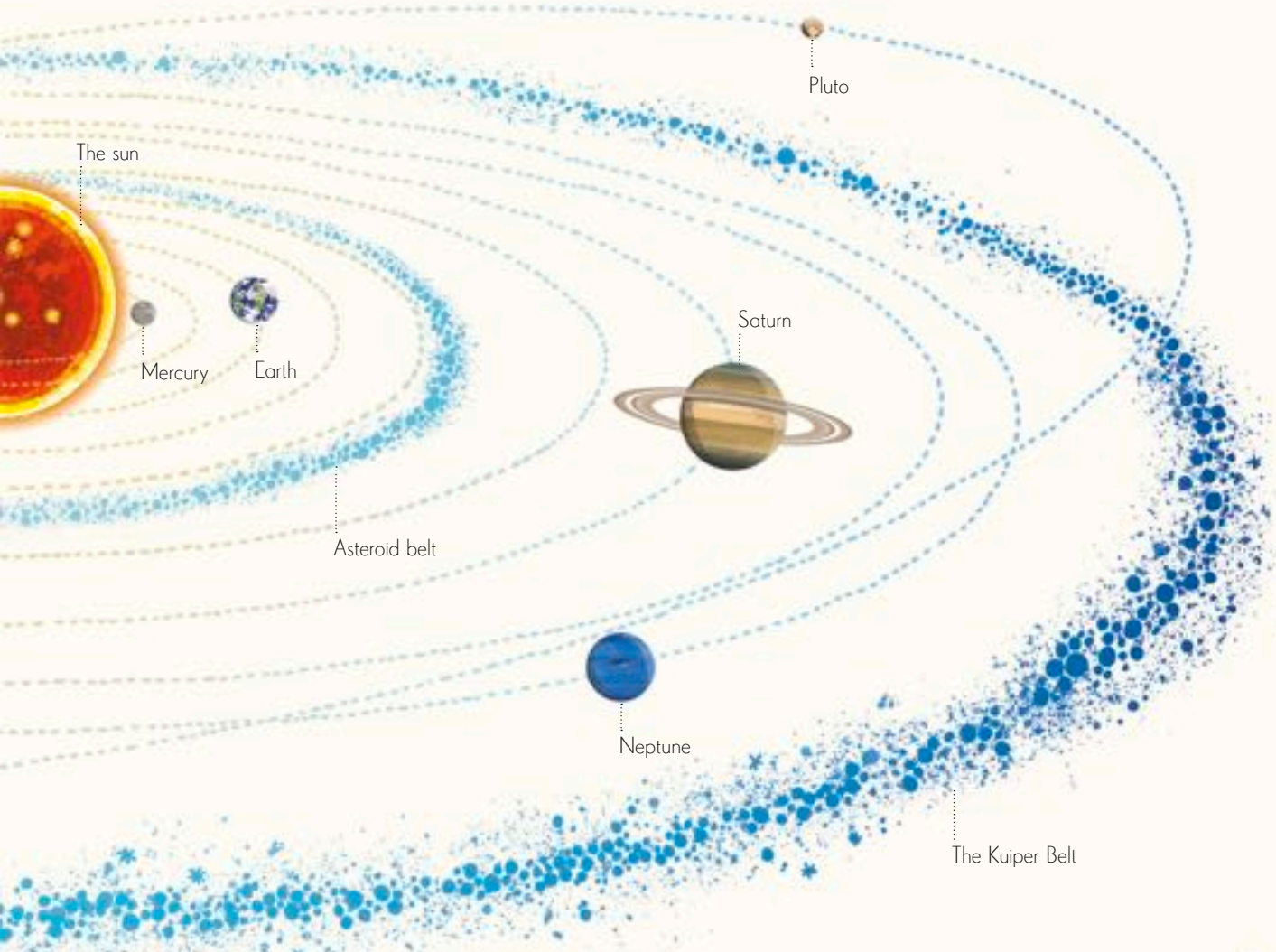
This total solar eclipse took place in 2016, and could be seen from most parts of Indonesia.

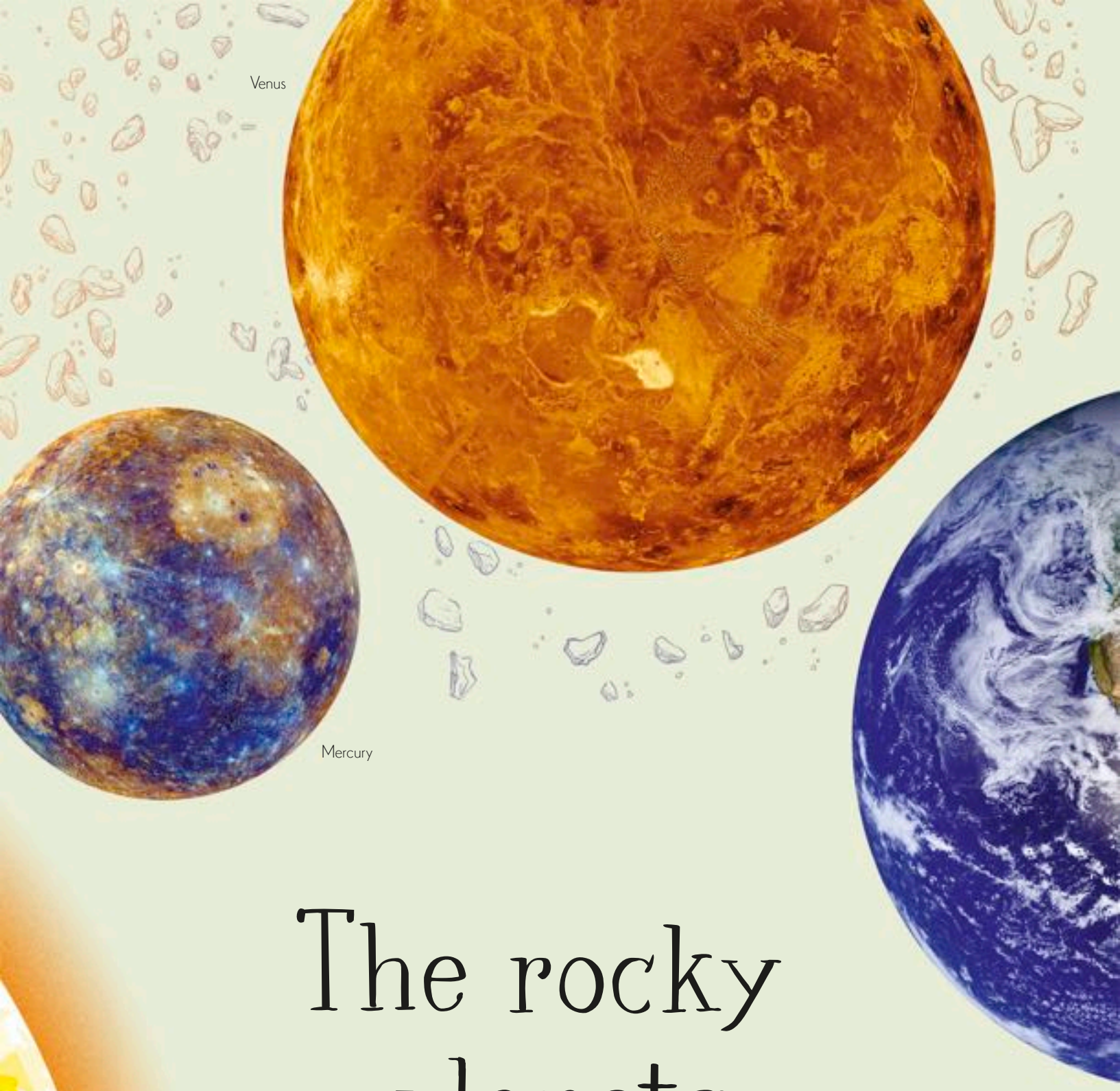
# The solar system

There may be another world orbiting at a huge distance from the sun–we just haven't discovered it yet!



The sun sits at the center of an enormous family of objects that whirl around it as they all move through the Milky Way. Together, this extraordinary collection is known as the solar system. It includes the eight main planets and their moons, and also a fascinating array of smaller worlds like Pluto and Ceres. It's also home to asteroids and comets—these objects are tiny compared to planets like Earth, but they swarm around the sun in vast numbers.



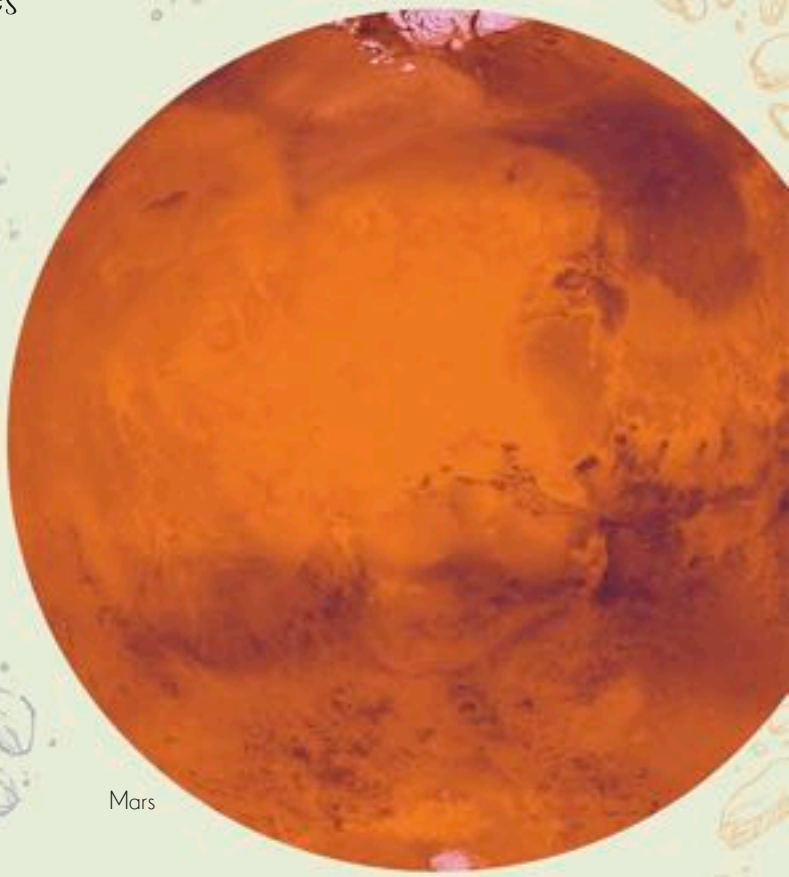



# The rocky planets

The sun · Mercury · Venus · Earth · Mars

Mercury, Venus, and Mars are close enough to Earth that we can sometimes see them without a telescope.

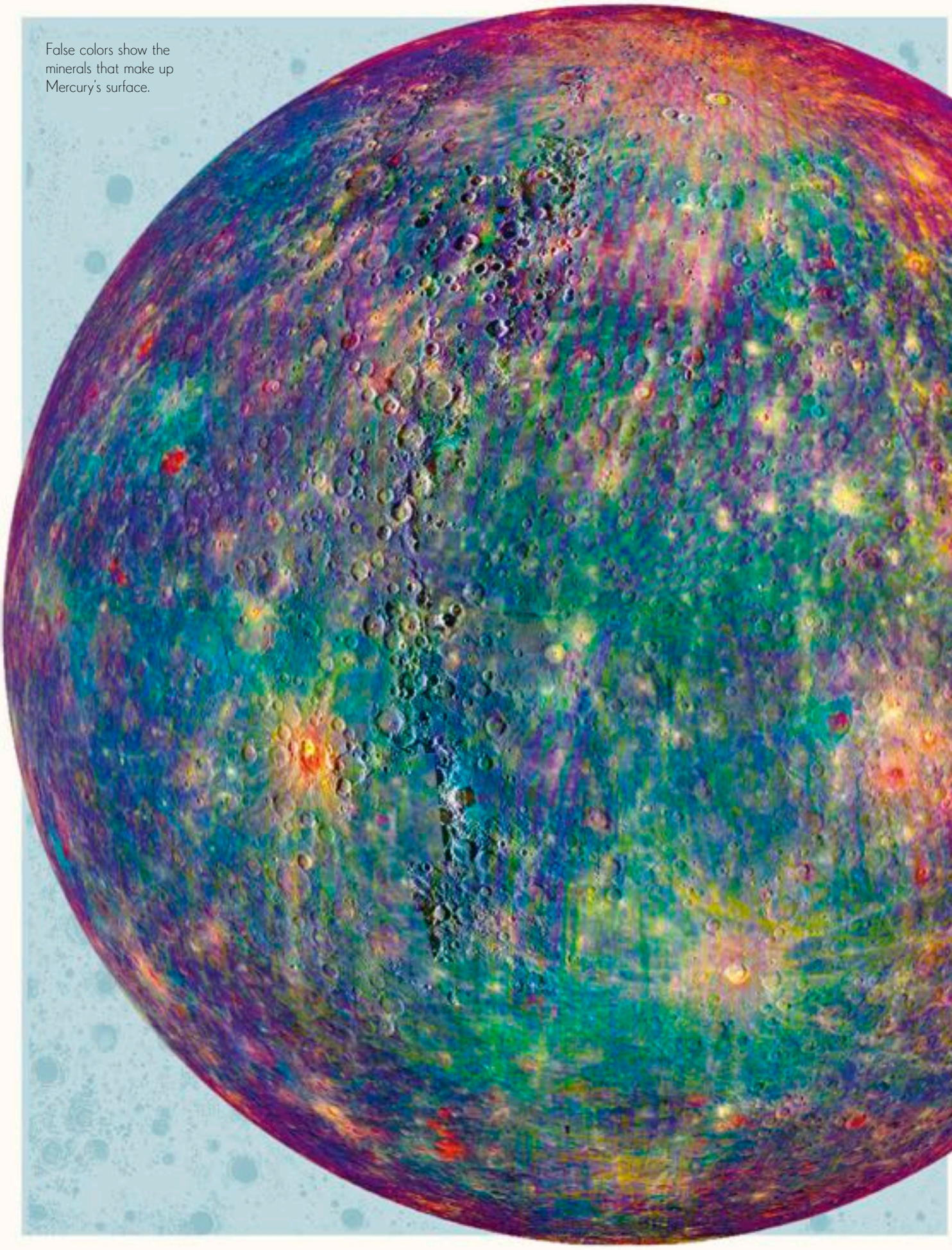
Earth



Mars

Huddled at the heart of the solar system are the four inner planets: Mercury, Venus, Earth, and Mars. Like the four larger planets farther out, these worlds are thought to have come from an enormous doughnut-shaped disk of dust and gas that encircled the newborn sun.

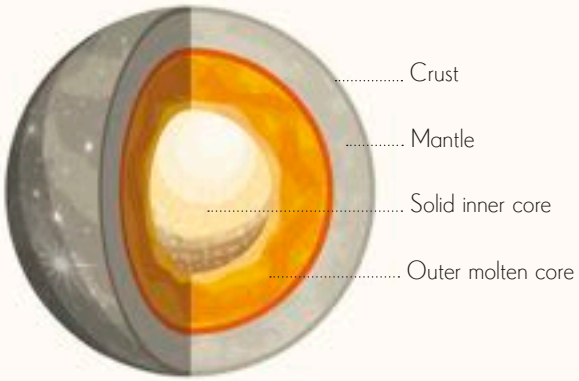
One theory says that, over time, small rocks and pebbles began to form within this disk. They collided and stuck to each other, eventually building much larger objects that merged into worlds. The inner planets are small and mostly made of rock and metal. Scientists think this is because the icy ingredients that helped make the distant gas giants couldn't have survived this close to the heat of the young sun.



False colors show the minerals that make up Mercury's surface.

At 3,032 miles (4,879 km) across, Mercury is the smallest planet in the solar system.

# Mercury




Inside Mercury

The planet Mercury is named after the quick-footed messenger of the Roman gods, which is fitting since it races around the sun, taking just 88 days to complete its orbit. Mercury is the closest planet to the sun, and its surface temperature can reach a blistering 806 °F (430 °C).

Its rocky crust shows the scars of asteroid and comet impacts, with almost its entire globe covered in craters. Yet Mercury holds surprises too. In its polar regions, there are places—at the bottom of deep craters—that the blazing sunlight cannot reach. There might be water ice lurking in these tucked-away shaded spots.

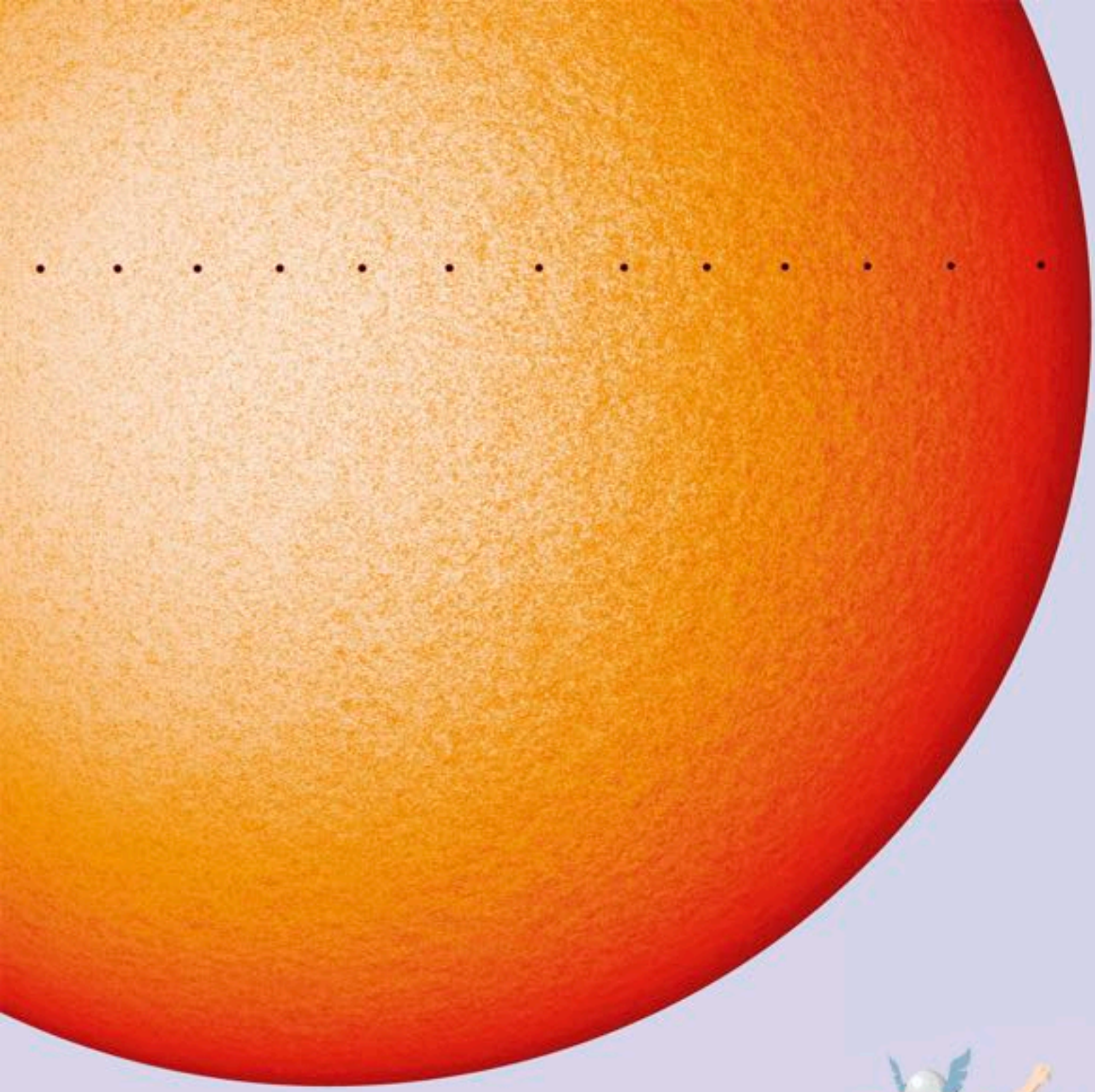
This image shows the transit of Mercury as it moved across the sun in 2019.

# The transit of Mercury

As the inner planets, Mercury and Venus, whirl around the sun, they sometimes swoop in front of its face, from the perspective of Earth. These events are quite rare, and they're called transits. The last transit of Mercury occurred back in 2019 and the next one will happen in the year 2032.

Professional astronomers use transits to discover worlds orbiting other stars far from our own solar system. They do this by using special space telescopes to record the brightness of these distant stars. If a star dims briefly, it may be a sign that a transit has occurred—that is, a planet has passed in front of the star and blocked a tiny bit of its light.

Remember, it's important to never look directly at the sun!



In 1629 a German astronomer named Johannes Kepler became the first person to predict a transit of Mercury.

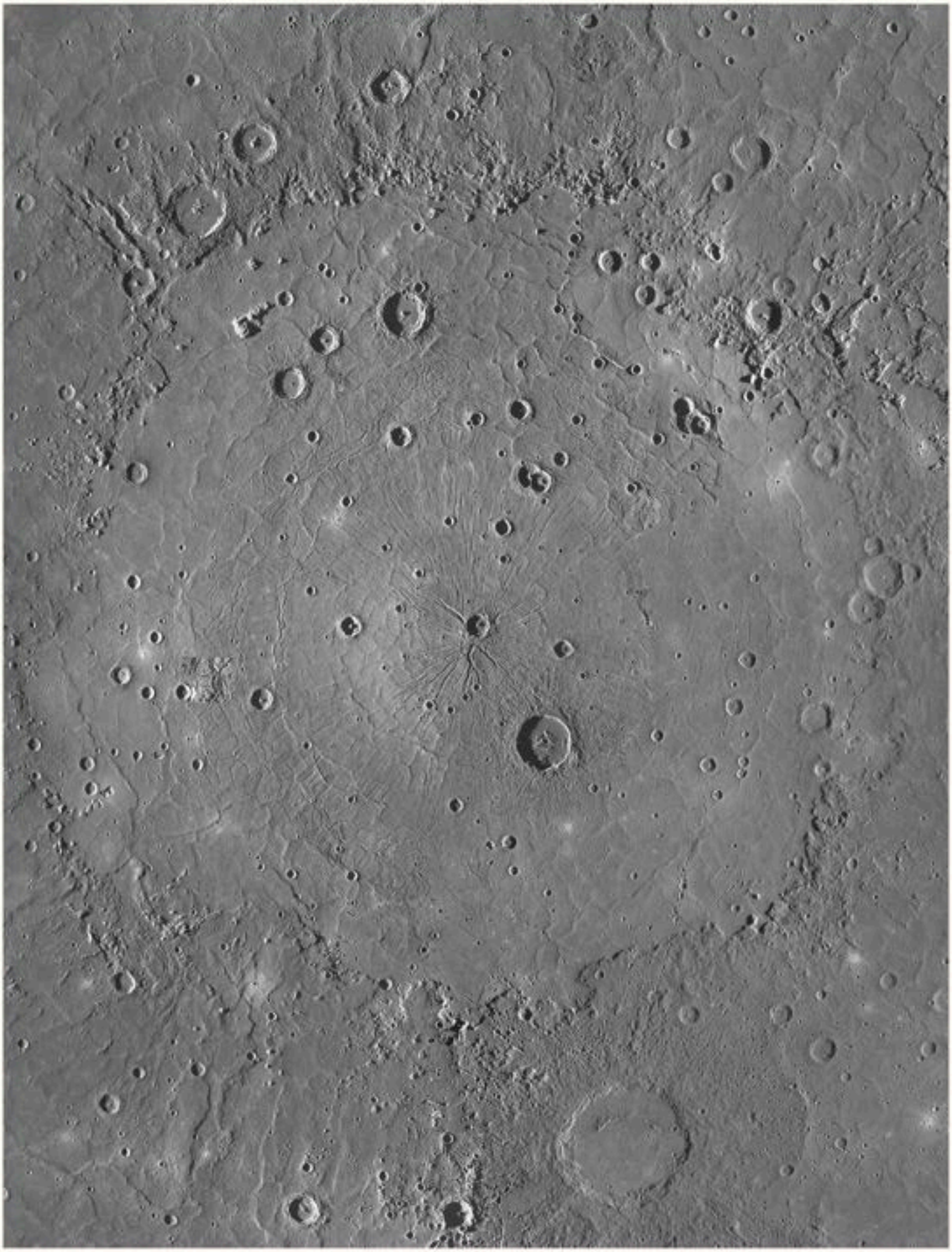
The impact that made the Caloris Basin was so violent it may have created hills on the opposite side of Mercury.

# Caloris Basin


Let's imagine you're a scientist trying to understand the amazing landscape in this picture of Mercury's surface. What do you think caused that huge, circular feature at the center? And were most of those smaller craters inside the circle formed before or after it?

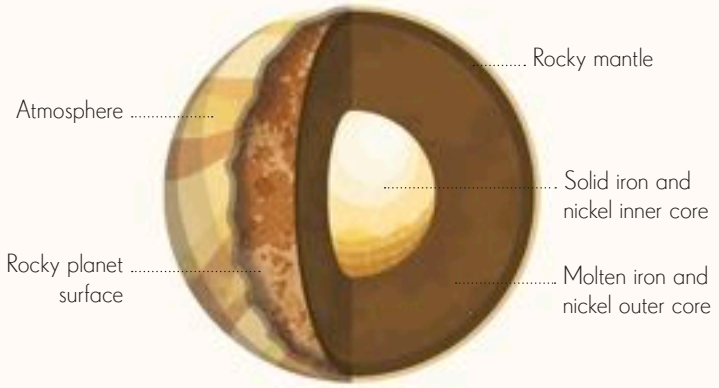
If you said this feature was made by an object—such as a massive asteroid—crashing into Mercury, you're absolutely right! That enormous ring is known as the Caloris Basin, and it is larger than the size of France. The smaller craters are on top of the features of the Caloris Basin, so they must have formed after it was made. This is the kind of detective work scientists do all the time to uncover the secrets of the solar system.

The Caloris Basin is peppered with hundreds of smaller craters.



# Venus

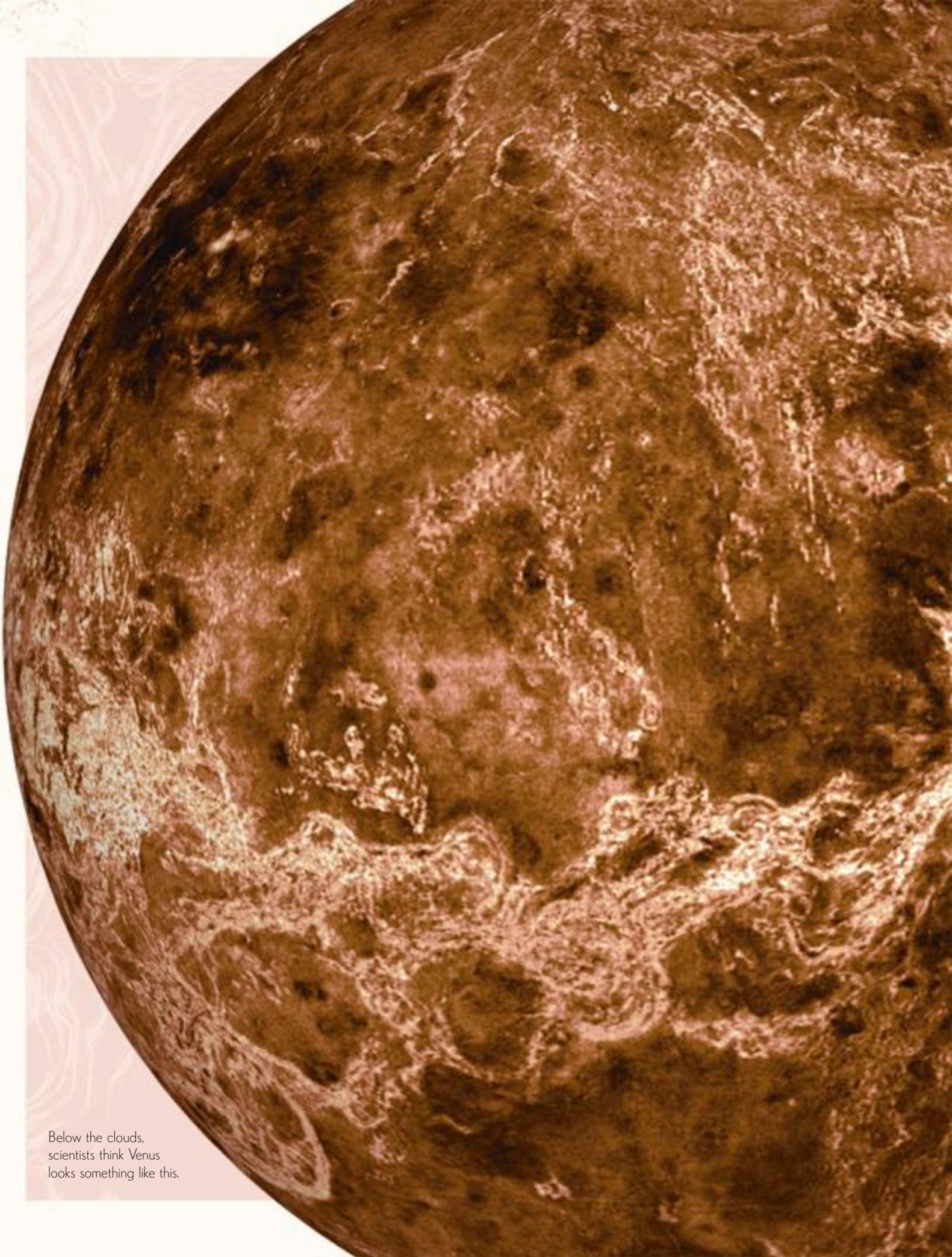
Venus is the second brightest natural object in our night sky, after the moon.




Inside Venus

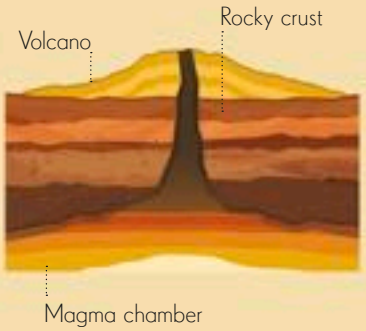
Even though it can float up to 162 million miles (261 million km) away from Earth, Venus is still one of our closest planetary neighbors. The two planets are almost the same size, so they are sometimes called twins, but their stories are very different.

Some scientists think that in the distant past, Venus had oceans of liquid water. These, however, have long since disappeared, and today all that remains is a volcanic landscape blanketed by thick clouds. What little we do know about the surface of Venus has come largely from a handful of space probes that have visited the planet. Some of these actually traveled down to the surface, where they experienced roasting temperatures of 860 °F (460 °C) and crushing pressure from the toxic atmosphere.



Below the clouds, scientists think Venus looks something like this.

One of the tallest volcanoes on Venus is named Maat Mons, after the Egyptian goddess of truth, Ma'at.

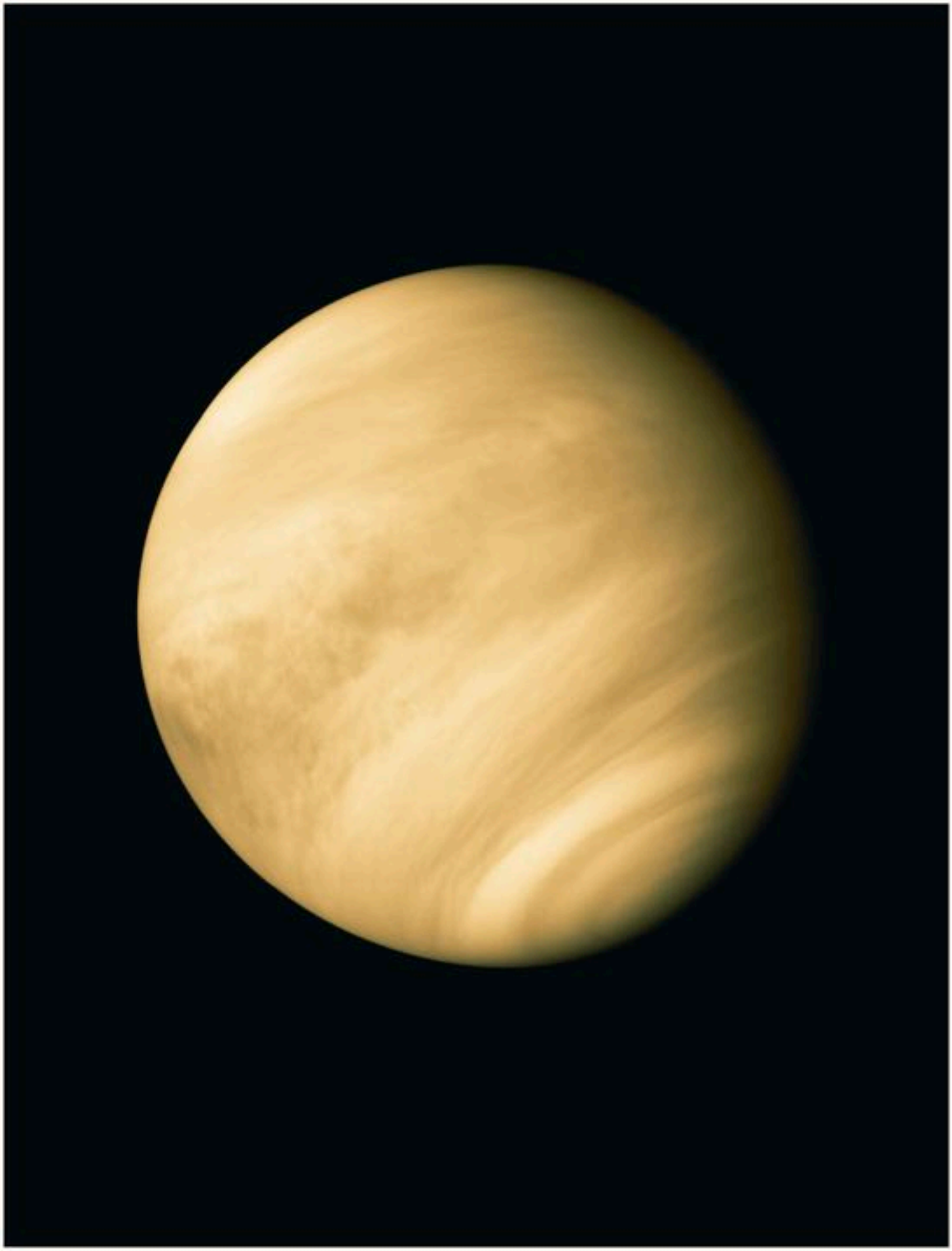



# Volcanoes on Venus

Venus is a world of many mysteries. Perhaps the most intriguing of them all is its barren, volcanic surface. Most of the planet is covered in enormous expanses of solidified lava. Ancient volcanoes rise up all over this bleak landscape, where a soft breeze stirs through the suffocating, hazy sky.

Some scientists think that about 500 million years ago, vast areas of Venus's globe were swamped by a series of spectacular lava eruptions. A few Venusian volcanoes may even be oozing lava today, but to find out for sure we'll likely have to send probes back to the planet for a closer look.

Maat Mons stands 5.5 miles (9 km) high.



Venus is named after the Roman goddess of love.

# Deadly clouds

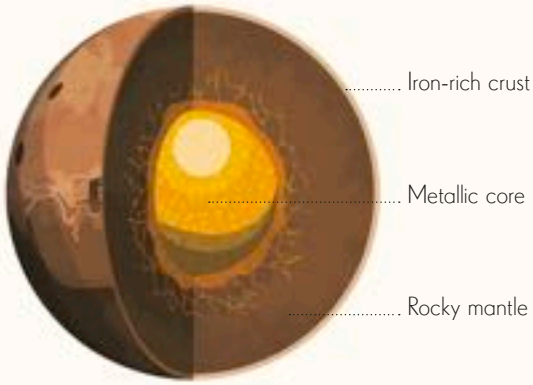
Sometimes Venus can appear in the dark sky as a dazzling point of light—one that easily outshines the other planets. What gives it this stunning sparkling quality? The answer lies in this picture: Venus's cloud tops are a bright, yellowish white.

Images from spacecraft that have visited the planet show enormous, billowing cloud patterns stretching right across the Venusian globe. Though these clouds may be pretty, they are laced with sulfuric acid, and they float in a thick, choking atmosphere rich with carbon dioxide. The top layers rain droplets of acid that evaporate before they hit the ground.

The clouds of Venus trap heat, making it the hottest planet in our solar system.

This picture shows a huge dust storm swirling over Mars.

# Mars




Inside Mars

As we travel away from the sun, we cross the path of a world that humans may one day visit: Mars. For centuries, humans have looked toward this little world and imagined what wonders might lie there. Today, we know more about the "Red Planet" than ever before.

As you read this right now, there's a good chance a rover or lander is exploring some part of the sandy, rocky surface of Mars, while spacecraft with cameras whirl above, snapping dramatic shots. We now know this is a planet covered in windswept plains, and scarred by vast canyons and enormous volcanic peaks. But the rocks and valleys of Mars also tell us that it wasn't always so desolate and dusty. Could life once have existed here?

Mars is named after the ancient Roman god of war, because its reddish color made people think of blood!

# Valles Marineris

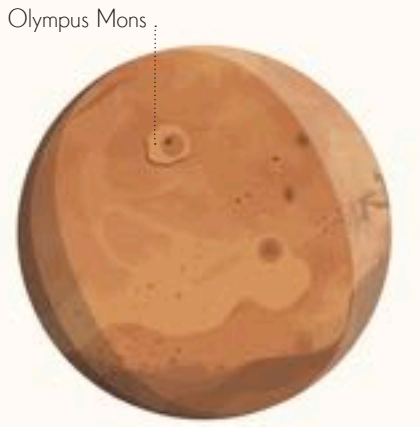
When astronauts travel to Mars in the future, one of the most spectacular features they'll see will be the Valles Marineris, or Mariner Valley. This immense canyon is a deep, roughly straight, gouge in the Martian surface that stretches an astonishing 1,367 miles (2,200 km) across the planet—longer than the entire length of Italy! Even today, the great mystery of the Valles Marineris is how it formed. Scientists have several ideas. For example, some believe the Martian crust split and a wide swathe slumped downward.


The walls of the Valles Marineris drop a hair-raising 6.2 miles (10 km) in some places. Earth's Grand Canyon looks tiny in comparison!

The Valles Marineris looks like a huge scar on the planet's surface.

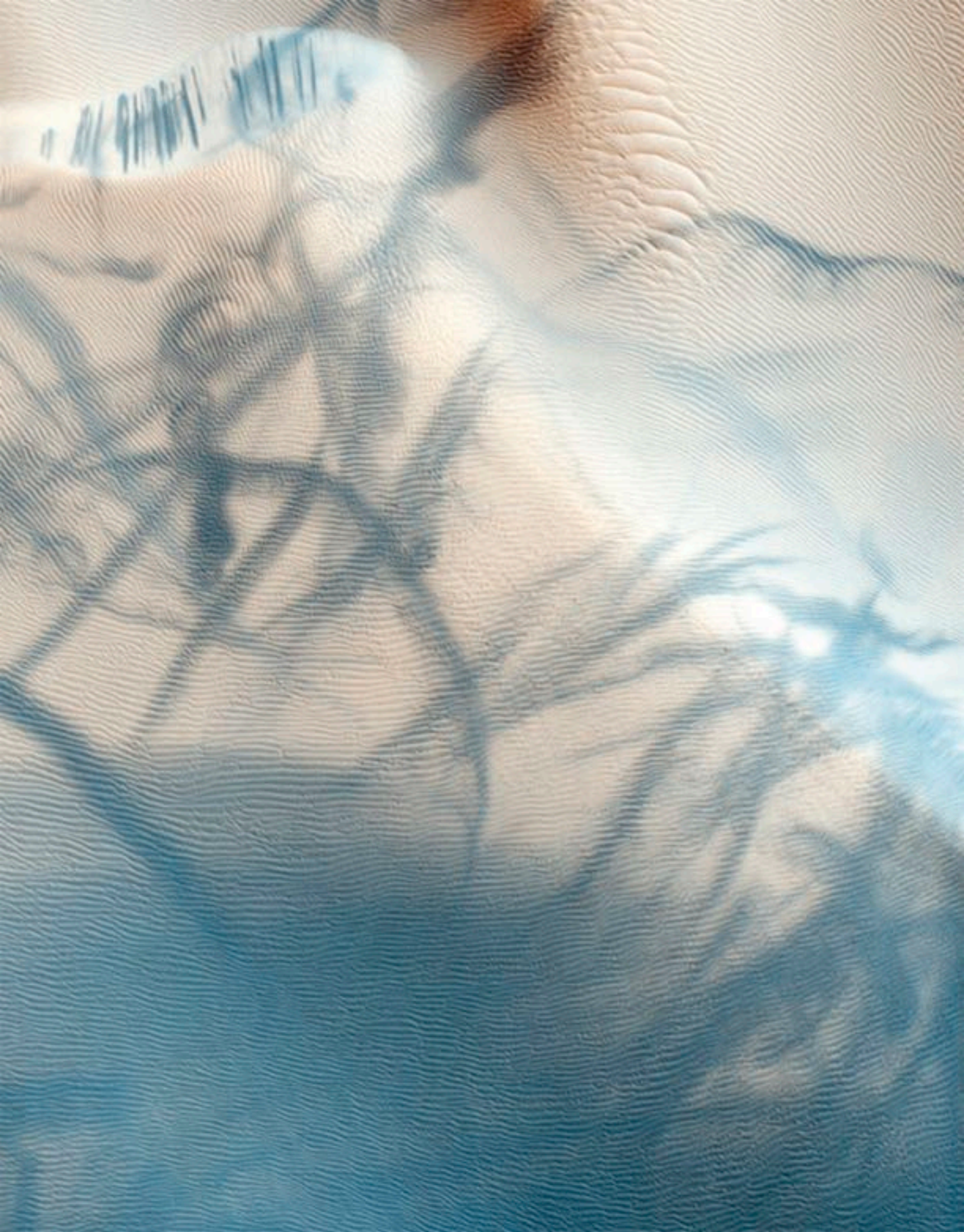
# Olympus Mons

Olympus Mons may look flat from a distance, but it's actually more than twice the height of Mount Everest.




When it comes to spectacular volcanoes, Mars takes the top spot. The mighty Olympus Mons is a shield volcano, which means it has a very broad base, with gently sloping sides. It's much larger than any volcano on Earth. From its base to its peak, it gradually rises a staggering 13.6 miles (21.9 km) into the Martian sky, while its sides span about 398 miles (640 km)—it would take a jet airliner more than 40 minutes to fly across it. It is thought that Olympus Mons formed about 3.6 billion years ago, when huge amounts of lava oozed from inside the Red Planet.

The pit at the top of Olympus Mons is about the size of Luxembourg!



# Martian dust devils

Look at these strange tracks on Mars's surface. It looks as if somebody has been scribbling in the Martian dust. In fact, it wasn't somebody, but something. Dust devils—spinning vortexes of air like little tornadoes—have whipped over the ground, leaving trails that record their path.

Several spacecraft have caught these whirlwinds in the act of flitting across the Red Planet. We now know there are other dusty phenomena in Mars's skies, too: enormous dust storms occasionally stir within the planet's atmosphere, enshrouding its globe in a murky, brown haze.

Dust devils leave dark marks on Mars's dusty surface.

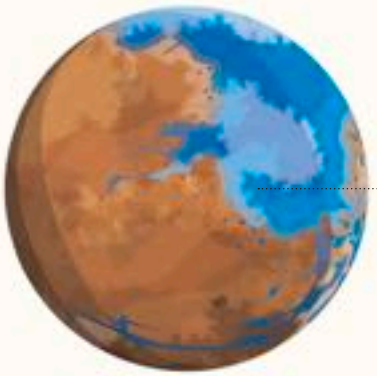
The wind on Mars has helped clean dust from the solar panels of rovers exploring the planet!

This image looks down on an ancient Martian river valley called Nirgal Vallis.

# Water on Mars

If you could somehow walk safely across Mars today, you'd probably only hear the sound of a soft breeze stirring across the landscape, or the occasional flurry of an enormous dust storm. Billions of years ago, however, you may have also been able to listen to the crashing of waves and the roar of a river carving its way through the Martian rock.

We think this because scientists have found clues, all over Mars, revealing how its surface was sculpted by large amounts of liquid water. Orbiting spacecraft have captured pictures of dried-up river valleys and lakes, while on the ground, rovers have found rocks and minerals that must have formed in a watery environment.



This is what Mars might have looked like many years ago!

Mars may have once had a large ocean in its northern hemisphere.

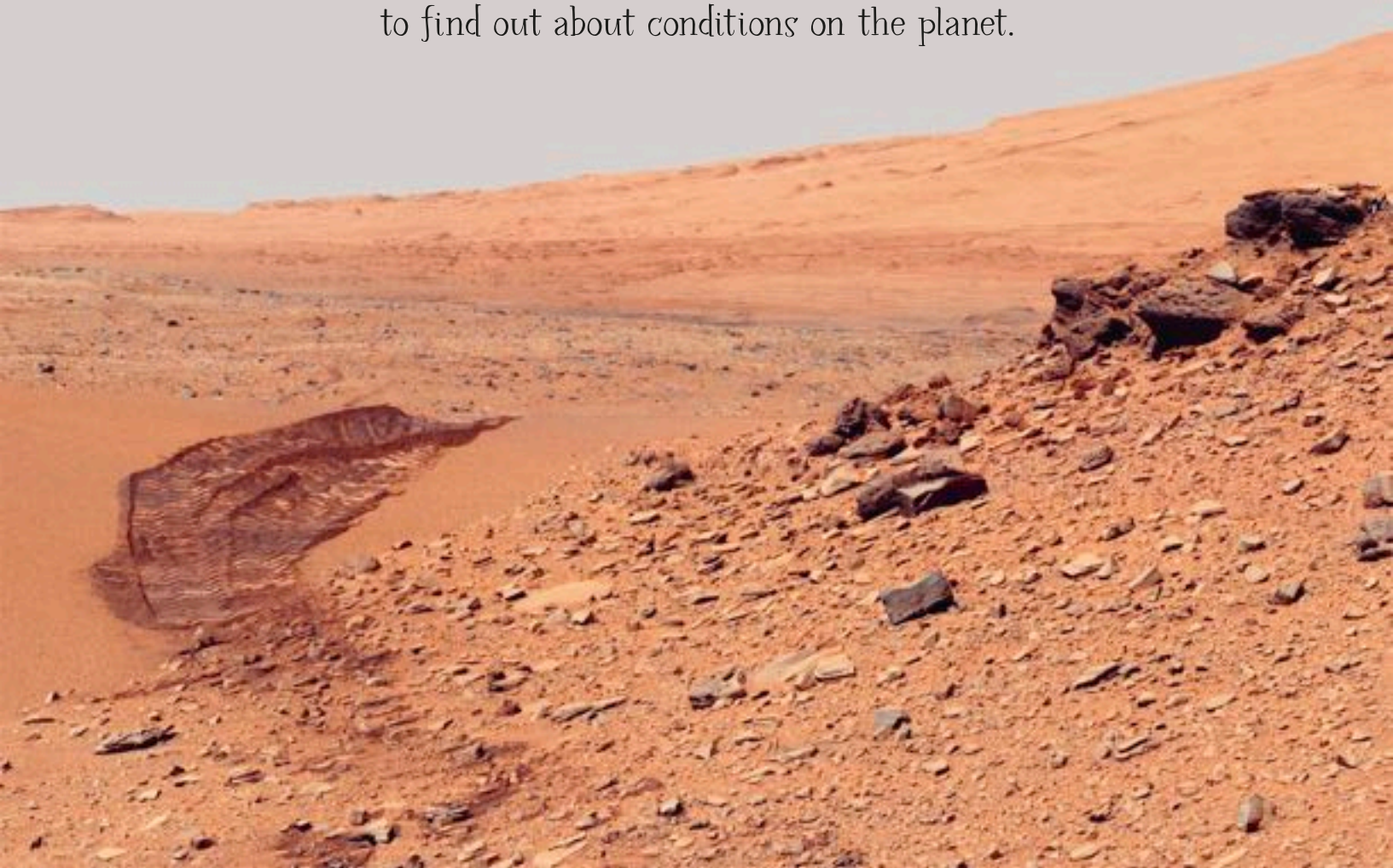
# Exploring Mars

Mars's color comes from iron oxide in its soil—the same stuff that makes rust orangey red.

The first humans to visit Mars might think it looks a little like home. Landscapes of rocky hills and craggy mountains loom over the brownish-red soil, while elsewhere valleys cut through desertlike plains and huge fields of sand dunes stretch to the horizon.

Under the hazy sky, though, these early explorers will soon see how different the Red Planet is from Earth. They will need protection from the sun's harsh ultraviolet light, and they'll have to trek across uneven terrain—Mars is peppered with craters, small and large. NASA's Curiosity rover has been roaming the planet for years, examining its atmosphere and geology. Future robotic missions will dig deep below the Martian surface to see if conditions there could support life.

The Curiosity rover landed on Mars in 2012
to find out about conditions on the planet.



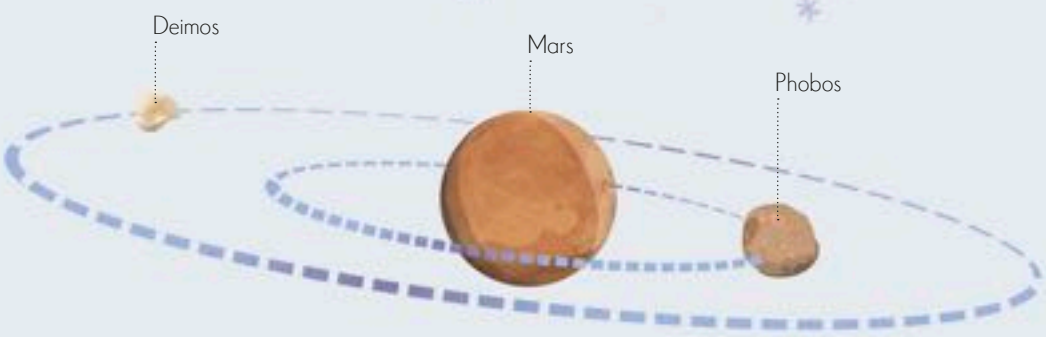
Deimos

Phobos and Deimos are named after the horses that pulled the Roman god of war's chariot.

# The moons of Mars

Mars has two moons, named Phobos and Deimos. At roughly 14 miles (23 km) in diameter, Phobos is the larger of the two—Deimos is about 7.5 miles (12 km) across. Scientists are not sure where these moons came from. They could be space rocks that were captured by Mars's gravity, or debris from a gigantic asteroid impact on the Martian surface long ago. The moons are oddly shaped and lumpy—this is because they aren't massive enough for their own gravity to squash them into a ball, like other, larger moons in the solar system.

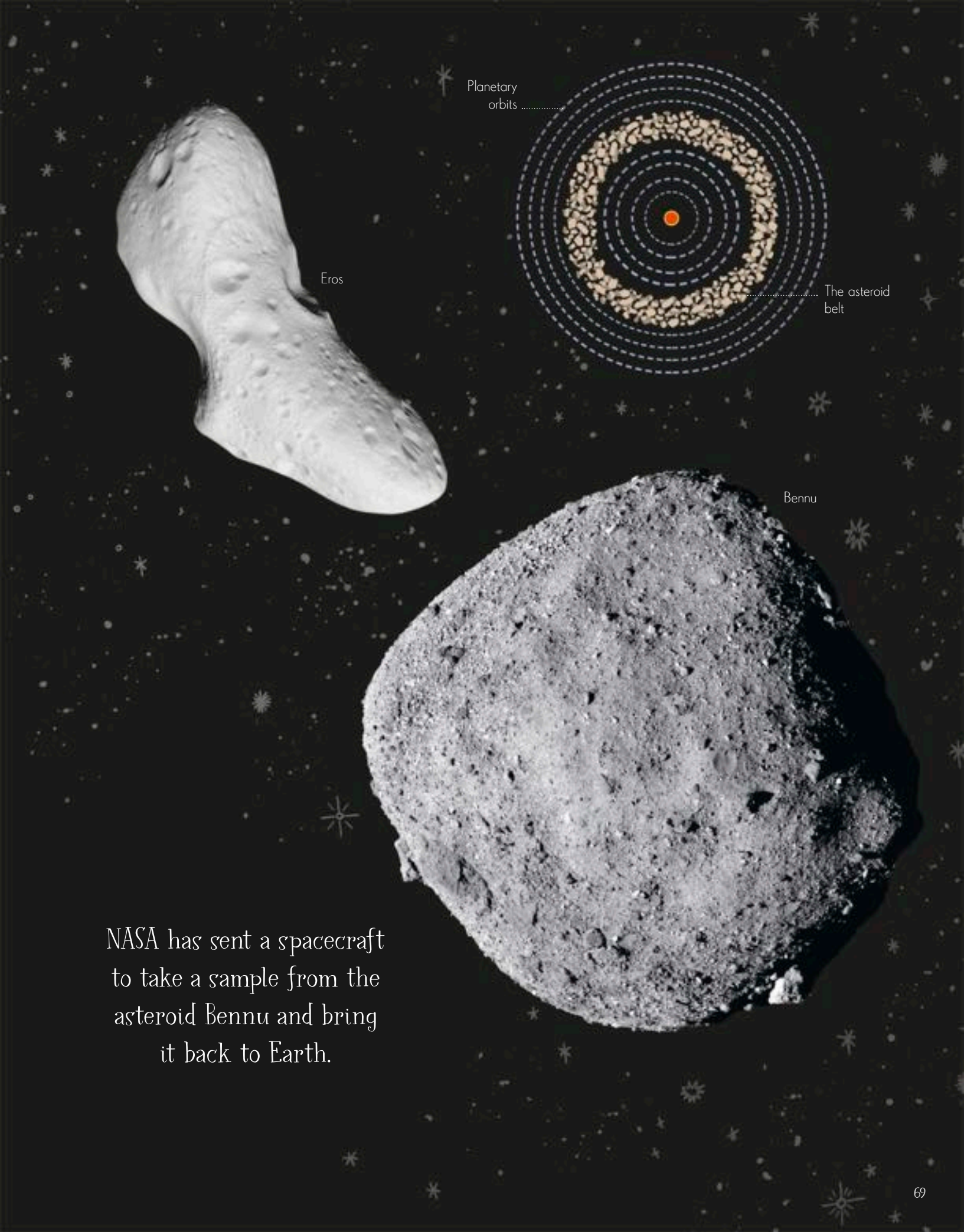
As it orbits around Mars, Phobos is, very slowly, moving toward the planet. In just over 30 million years, it may even fall onto the Martian surface. Imagine seeing that!


Deimos
Mars
Phobos


Phobos


# Asteroids

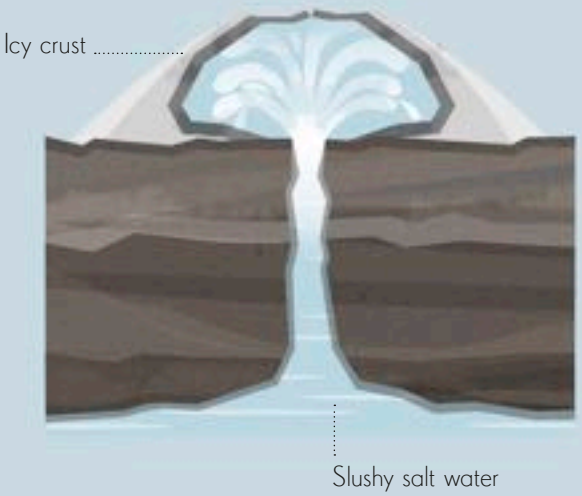
Did you know that the solar system swarms with thousands upon thousands of lumpy objects called asteroids? Asteroids are the materials that were left over after the planets finished forming. Some are quite rocky, while others are thought to be made of different kinds of metal. Many of the asteroids in our solar system lie in a huge ring between Mars and Jupiter called the asteroid belt, but there are many others scattered all over, and probably more out there that we haven't spotted yet!




NASA has sent a spacecraft to take a sample from the asteroid Bennu and bring it back to Earth.

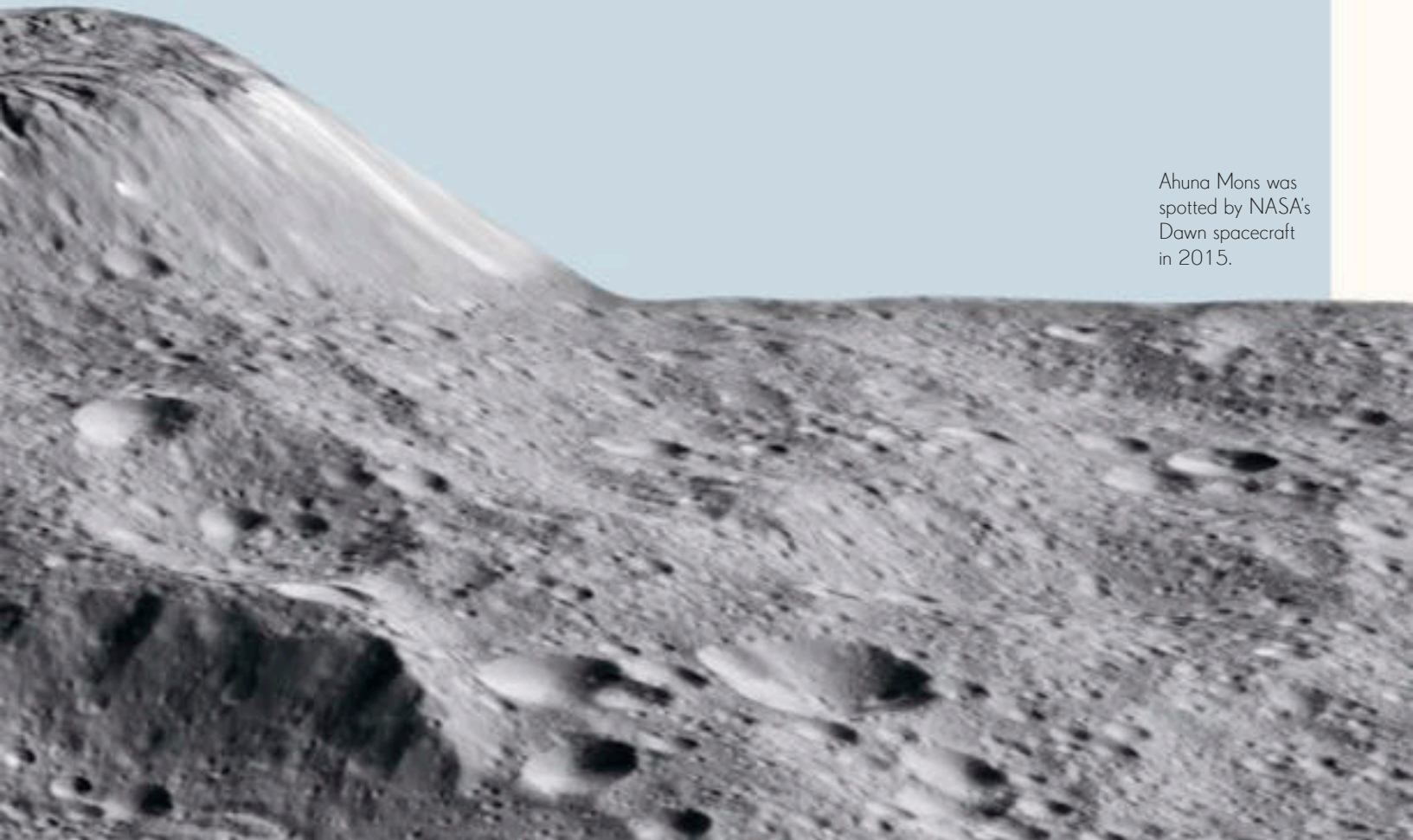
# Ceres

Ceres is one of five dwarf planets in our solar system.

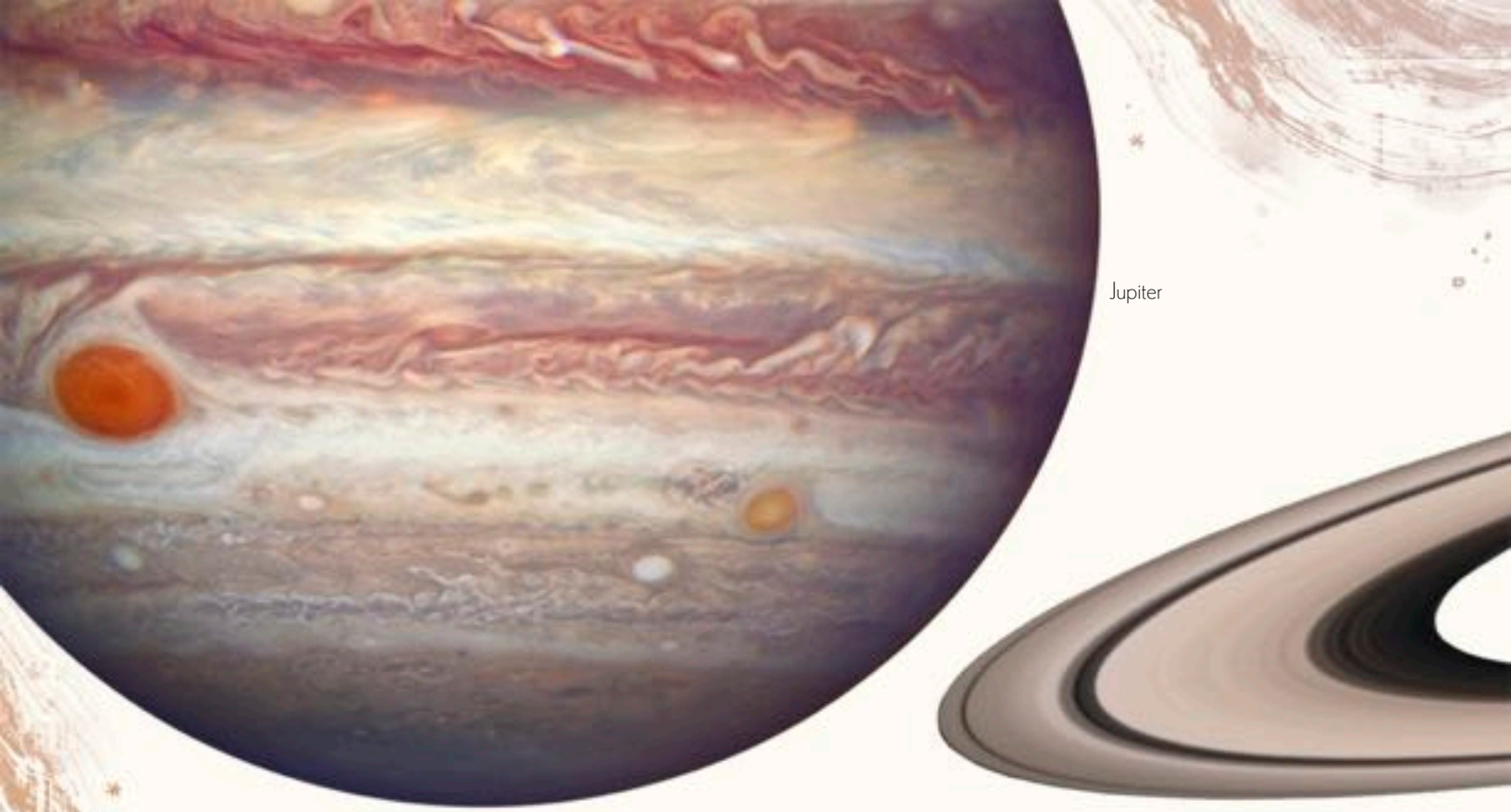


Inside the main asteroid belt between Mars and Jupiter, there is a place that may be key to understanding how the rocky inner planets of our solar system formed. This rounded object is named Ceres and at around 583 miles (940 km) across, it is far larger than many of the other lumpy inhabitants of the belt.

Scientists are captivated by Ceres because it seems to have huge amounts of water ice underneath its surface, so studying this cratered, frozen globe could give us clues about how our planet got its oceans. One of the features of Ceres, a peak known as Ahuna Mons, may be a cryovolcano. These are volcanoes that form from eruptions of slushy salt water rather than molten rock.

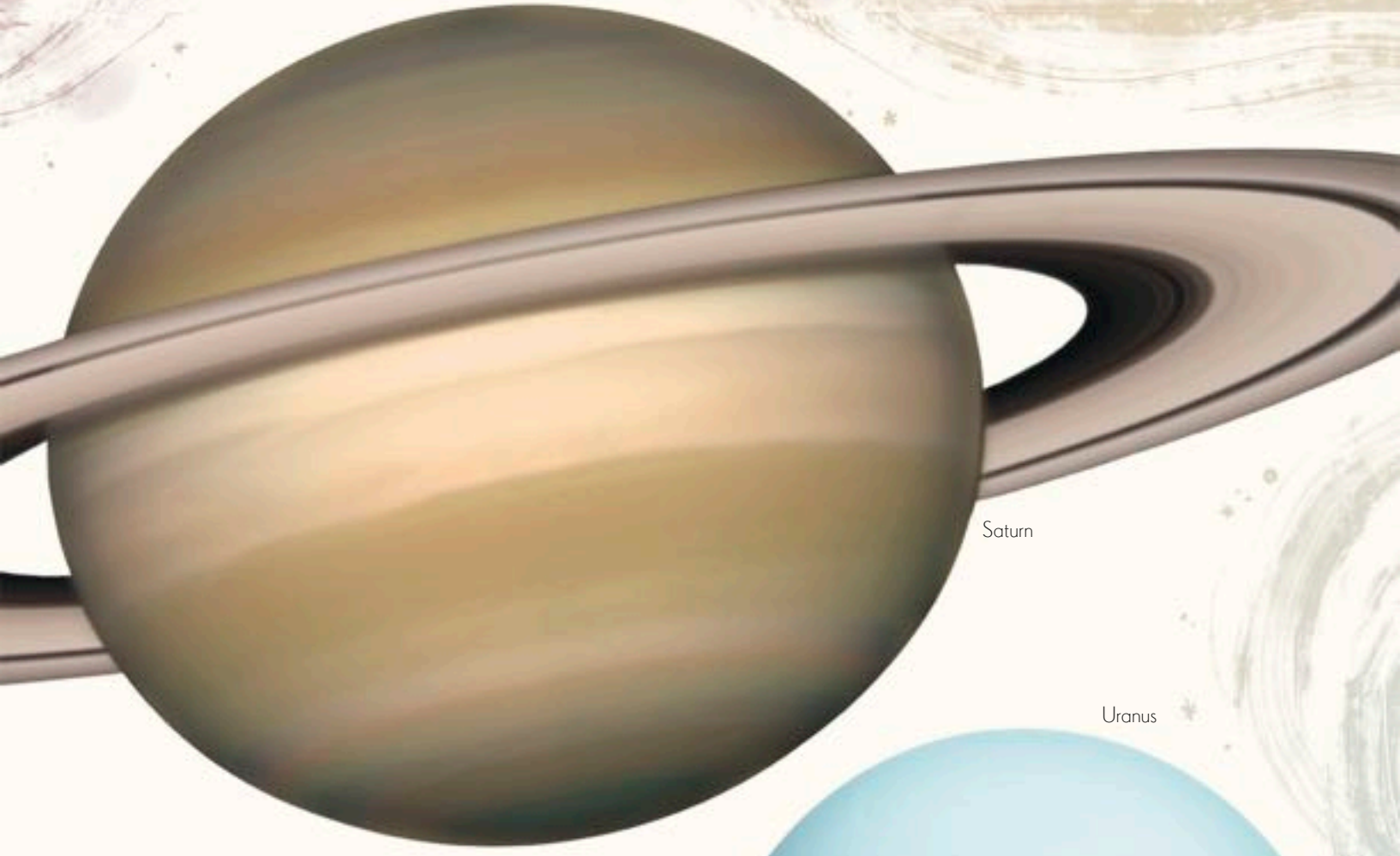


Ahuna Mons was spotted by NASA's Dawn spacecraft in 2015.




# The gas giants

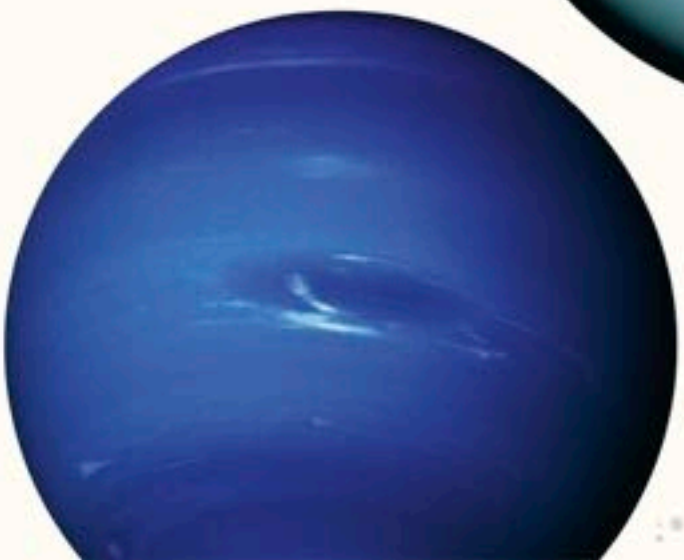
Beyond the rubble of the asteroid belt is the realm of the giant planets in our solar system—Jupiter, Saturn, Uranus, and Neptune. These four worlds, with their thick atmospheres made up of gases such as hydrogen and helium, are spread out over vast distances. Some scientists think that billions of years ago the gas giants jostled around within the solar system. As this happened, their orbits around the sun moved, and some may have even switched places! These dramatic changes scattered asteroids and other small objects in different directions. What was left is the planetary neighborhood we can see through telescopes today.



Saturn

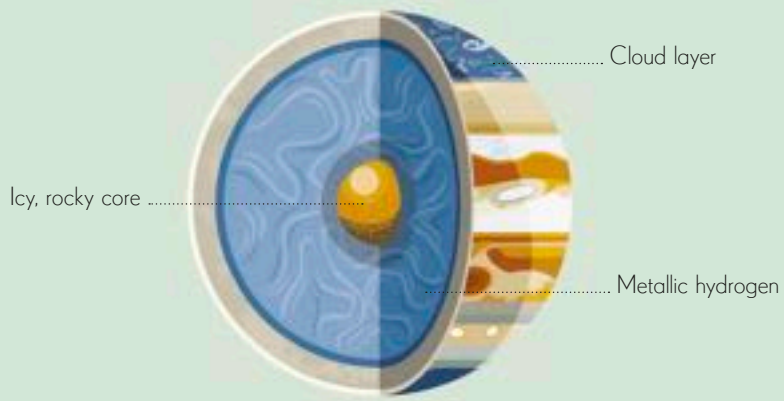
Uranus

The smallest gas giant is Neptune–and it's still almost four times larger than Earth.



Neptune

The shape of a dolphin lurks in Jupiter's cloud patterns. Can you spot it?

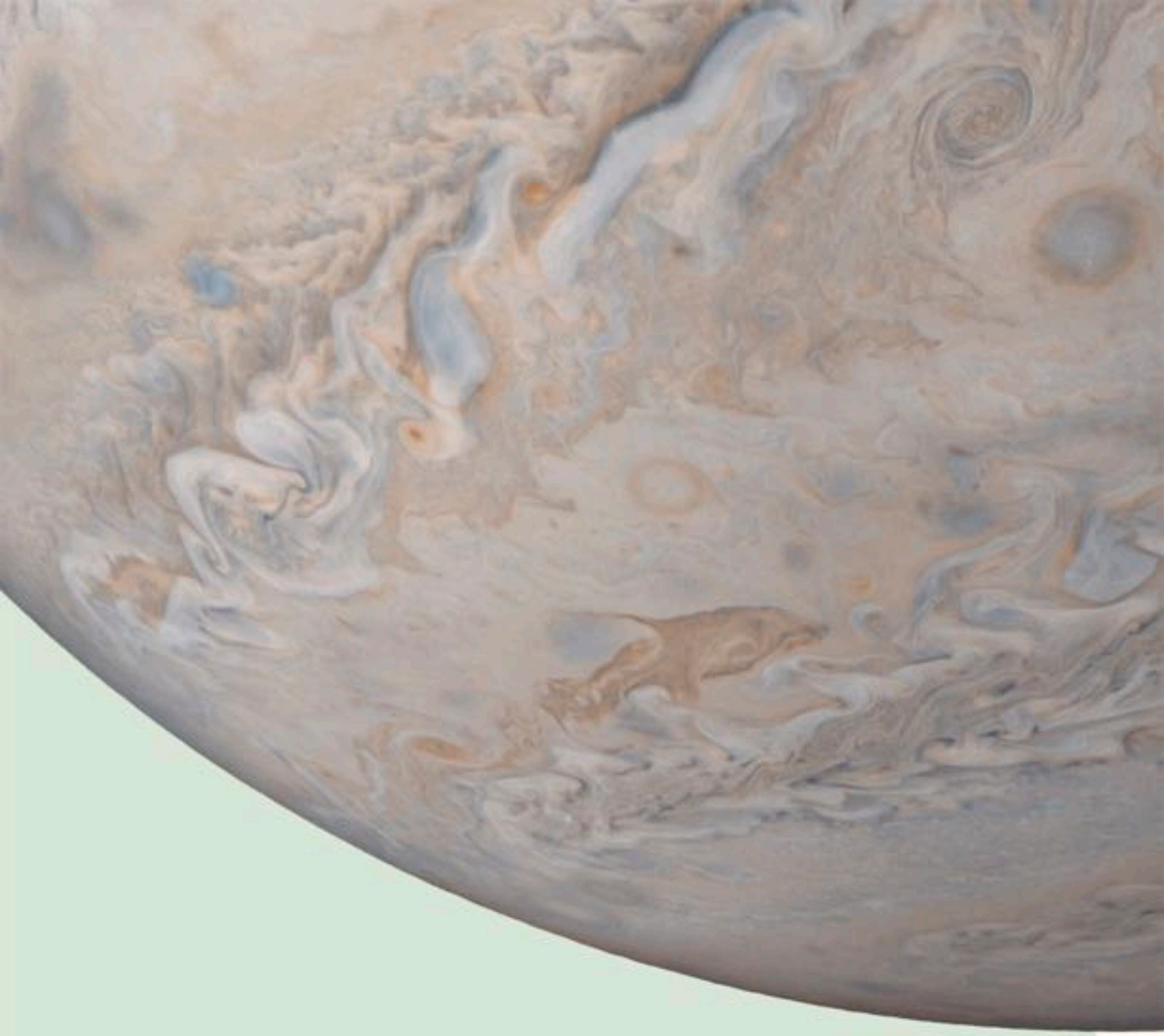



Inside Jupiter

# Jupiter

Jupiter is the largest world in our solar system—so big that it could fit just over 11 Earths across its face. This tremendous size means that, despite it being far away from our planet, we can sometimes see it in the night sky as a shining point of light.

If you look really carefully, using a good pair of binoculars, you might be able to spot Jupiter's four largest moons—Io, Europa, Ganymede, and Callisto. The moons will look like little starlike specks close to the bright planet. As these moons travel around Jupiter they change position night by night, so occasionally all four aren't visible from Earth at the same time. Today, we know there are at least 79 moons in total orbiting Jupiter—but there may be other tiny ones that nobody has spotted yet!



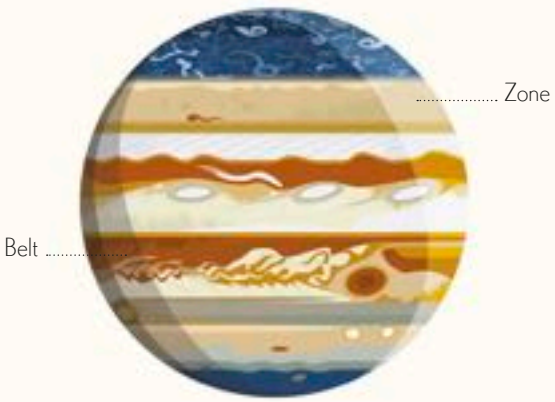
Jupiter's day is only 10 hours long.
It spins so quickly that its
middle bulges out!

Jupiter's atmosphere is mostly made up of hydrogen and helium, but it also contains other gases like smelly ammonia.

# Swirling clouds

If you could fly above Jupiter and look down on its clouds, this is the kind of view you would have. Huge swirls and pastel-colored ripples would stretch into the distance as far as the eye could see. Some clouds would tower so high they would cast enormous shadows onto the cloud layers below them. And if you watched long enough, you'd see that the planet's entire atmosphere is flowing and churning.

If your imaginary spacecraft zoomed higher, you'd notice that Jupiter's globe is striped—astronomers call the lightly colored atmospheric bands "zones" and the darker parts "belts."



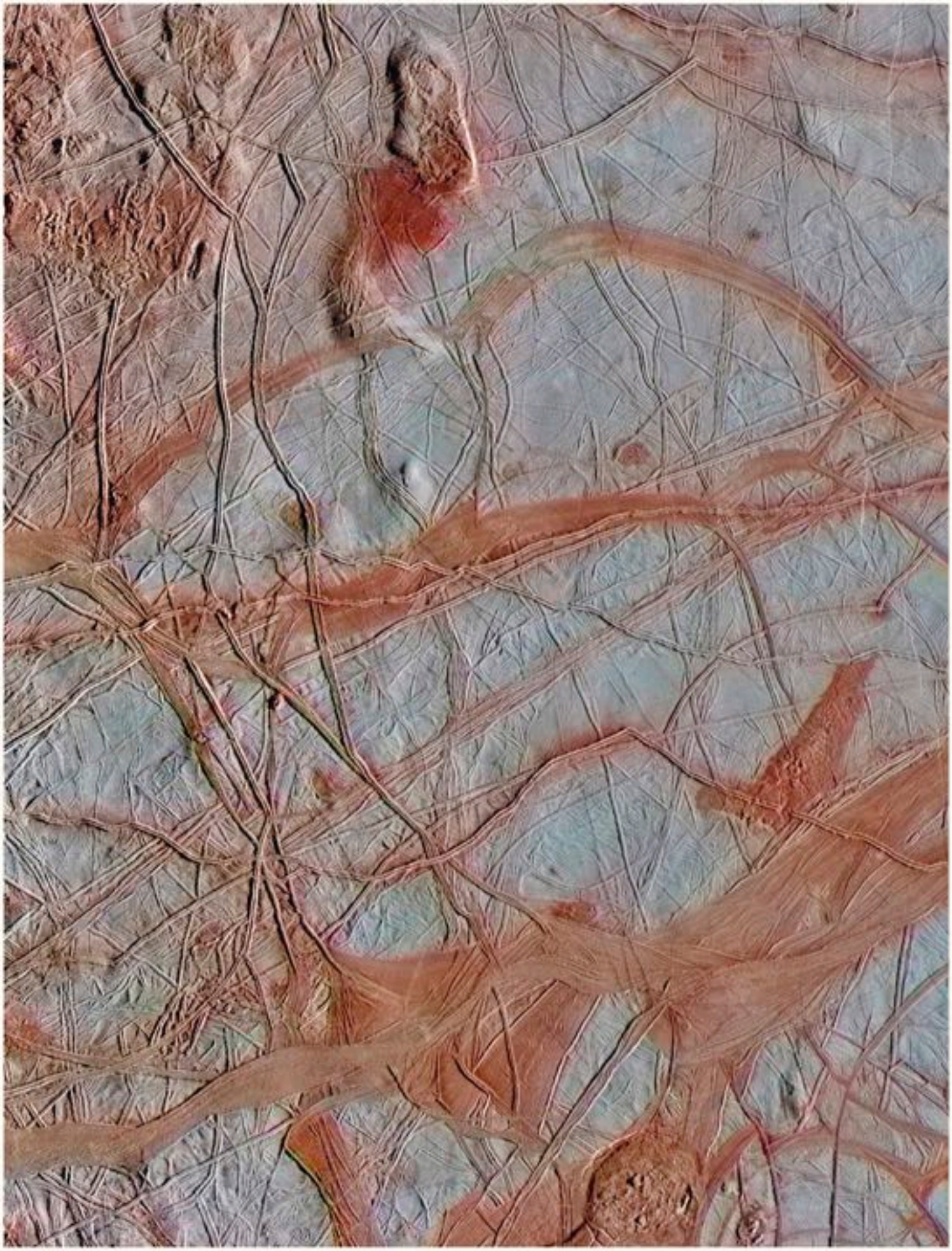

This colored image shows the clouds of Jupiter in its northern hemisphere.

# Stormy planet

Jupiter is named after the Roman king of the gods. He was also the god of the sky and thunder.

Jupiter's thick atmosphere is home to countless violent, swirling storms. They come in all sizes, from small ones that form and die quickly, to huge, spinning spots that can last for months and even years! The biggest storm on Jupiter is also the most famous in all the solar system. It is called the Great Red Spot, and for good reason—it's bigger than Earth, and its whirling orangey-red clouds have been raging for over 180 years, possibly even longer!

Over the years, the Great Red Spot has varied in size and shape.



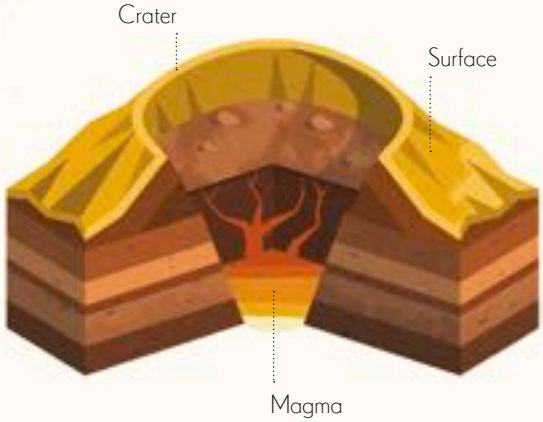
# Europa

In some places, the ice that makes up Europa's crust could be thicker than Earth's deepest ocean!

Jupiter's moon Europa is a fascinating place. It was first spotted by the Italian stargazer Galileo Galilei in 1610, so is known as one of the four "Galilean" moons. It is covered by a thick, icy crust that has relatively few craters on it. Huge fissures and giant cracks stretch all across its frozen surface, and it has strange red-brown markings that scientists still don't fully understand.

Under Europa's fractured crust it is thought that there is a layer of liquid water. For this reason, astrobiologists—people who study whether, and how, life might exist on other worlds—are intrigued by this captivating moon. Could anything be living in this dark and distant ocean beneath the ice?

This picture shows Europa's cracked surface.




# Io and its volcanoes

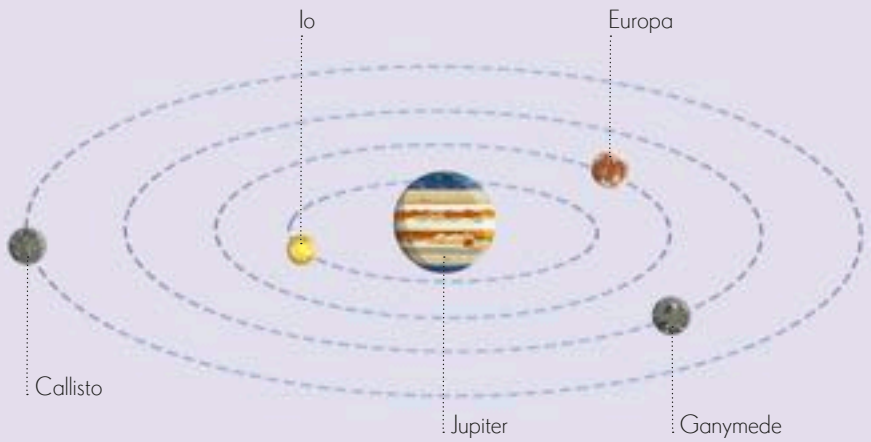
Can you imagine walking across the landscape on Jupiter's moon Io? It wouldn't be a particularly fun experience. Io's extraordinary bright yellow color comes from the smelly, toxic chemical sulfur. It's produced by the incredible amount of volcanic activity on this little world.

You see, Io is a moon that's pockmarked by many volcanoes—some of which are probably active and erupting right now. From the spacecraft that have visited Jupiter and its family of moons, we know there are seething pits of lava bubbling away on Io's surface, and huge volcanic eruptions blasting fountains of sulfurous gases high up into space. If you're ever planning a trip around the solar system, Io is definitely a place to avoid!

The Galileo spacecraft has spotted signs of over 100 volcanoes on Io.

Io was photographed by NASA's Galileo spacecraft in 1999.

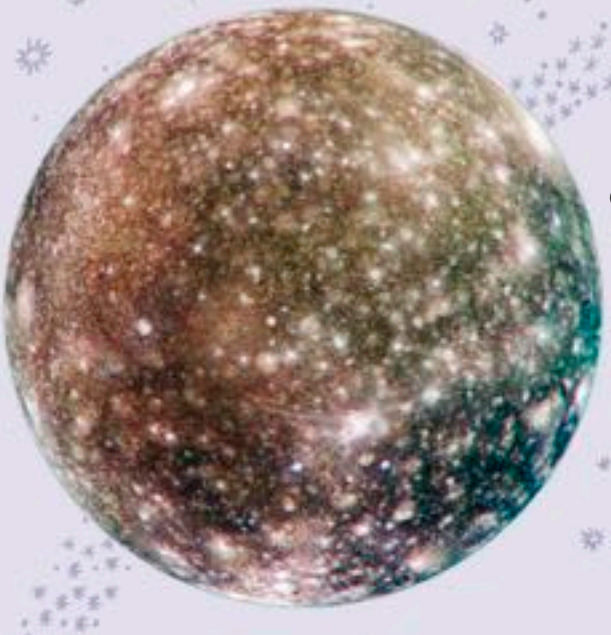
# Callisto and Ganymede




Jupiter and its four largest moons

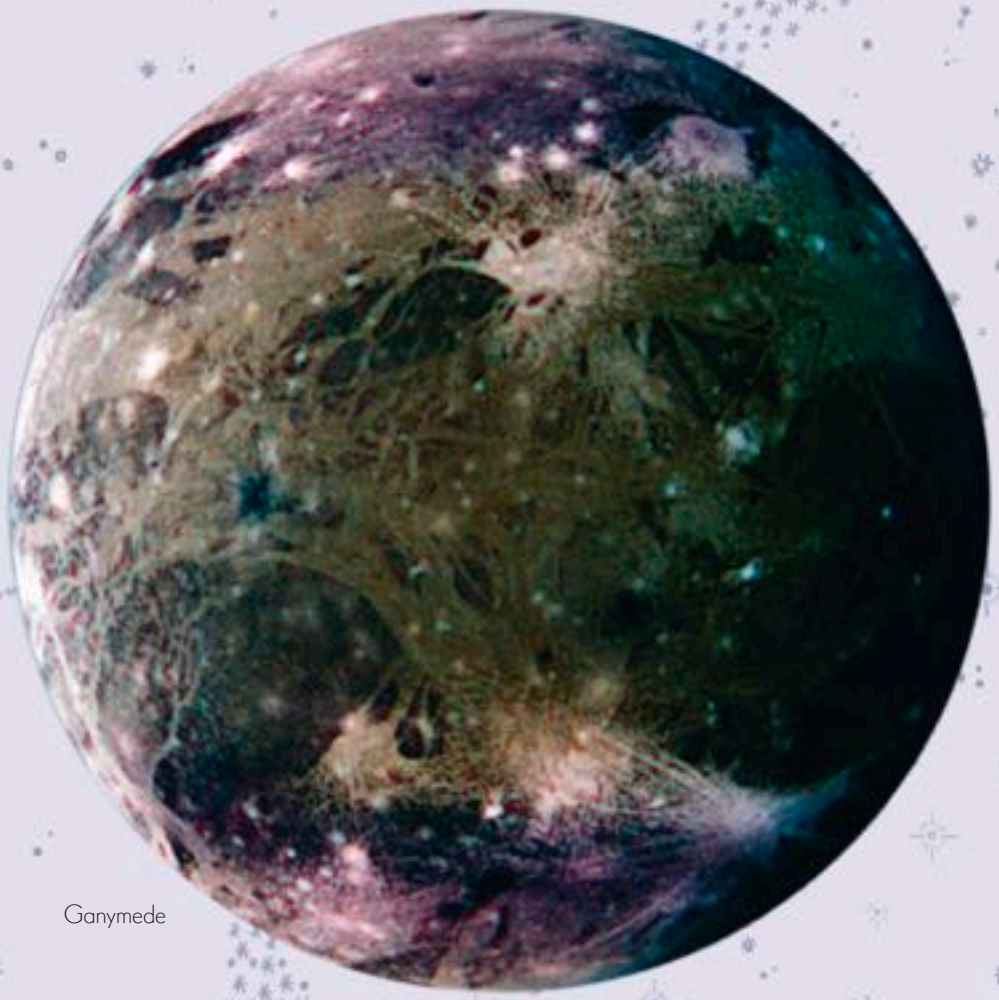
Callisto and Ganymede are two of the largest moons in the solar system. In fact, Ganymede is bigger than the planet Mercury! Like many of the objects in our planetary neighborhood, these moons are dotted with craters. Although they might look like spheres of rock at first glance, they both actually have cold, icy surfaces.

Scientists are planning to send a spacecraft to Jupiter to study these worlds in 2022. This mission may uncover some of the secrets of what Ganymede and Callisto are made of, and what lies beneath their frozen exteriors. This could tell us if these moons, and others like them, have places where life may be able to exist. The mission is named JUICE—or JUpiter ICy moons Explorer!



Callisto

Callisto and Ganymede may have liquid water oceans hidden deep below their surfaces.

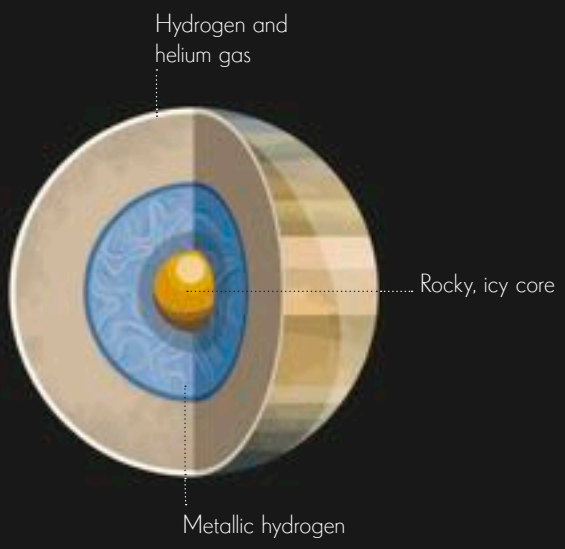


Ganymede

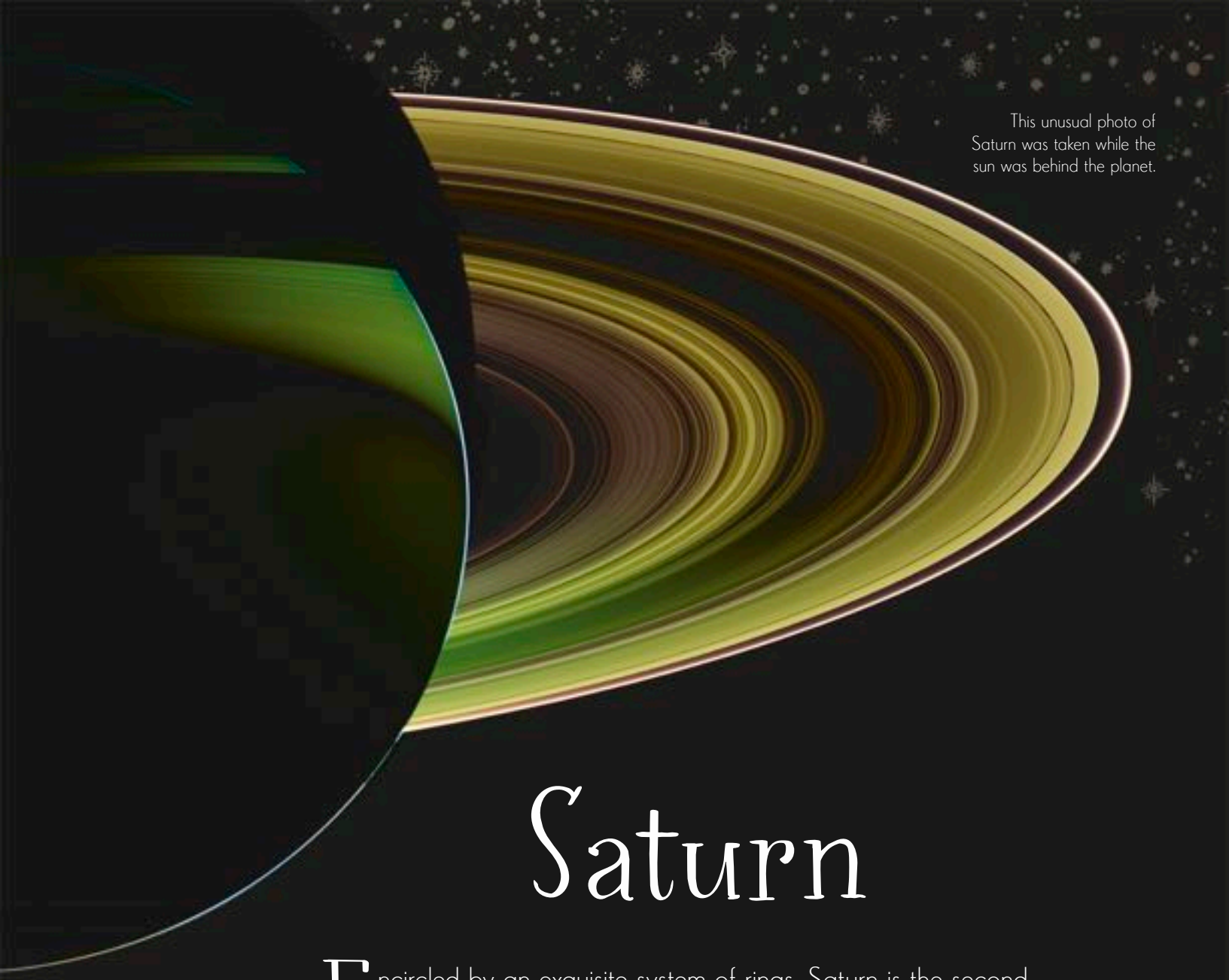
Enceladus

Tethys

Like Earth, both Saturn and Jupiter have auroras in their polar regions.




Inside Saturn



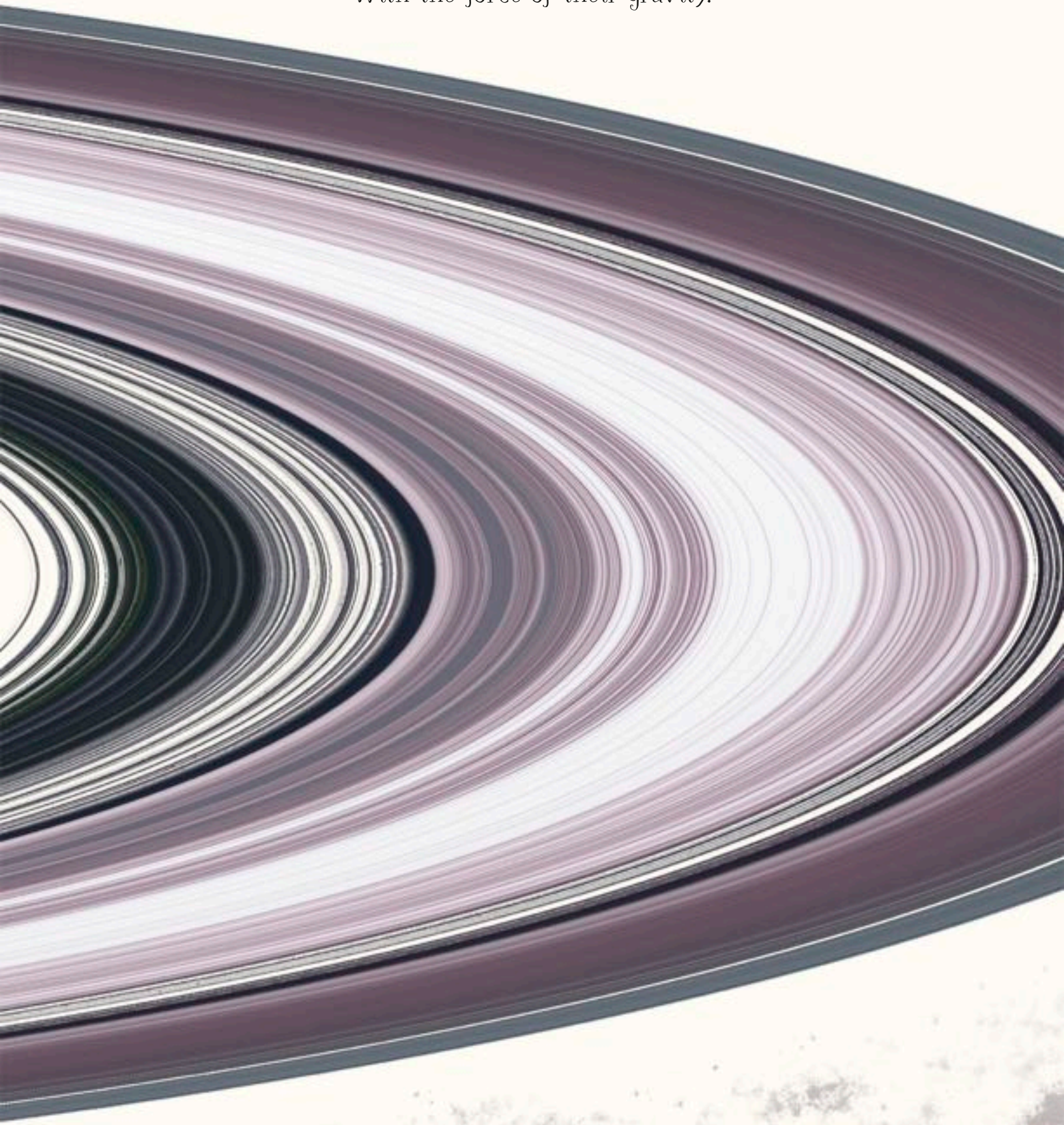
This unusual photo of Saturn was taken while the sun was behind the planet.

# Saturn

Encircled by an exquisite system of rings, Saturn is the second largest planet in our solar system—just like its neighbor, Jupiter, it's a giant world made mostly of gas, perhaps with an icy and rocky core. Even though Saturn is very large, it isn't very dense—if it were possible to build a swimming pool big enough, Saturn would float in it!

Saturn has 82 moons, making it the planet with the largest known family of moons in the solar system. Some of its moons are large and spherical, such as Enceladus (see p. 94), and some are small potato-shaped objects that dance gracefully near the edges of the rings. Others have very strange forms indeed, such as Hyperion, which looks like a puffy sponge!

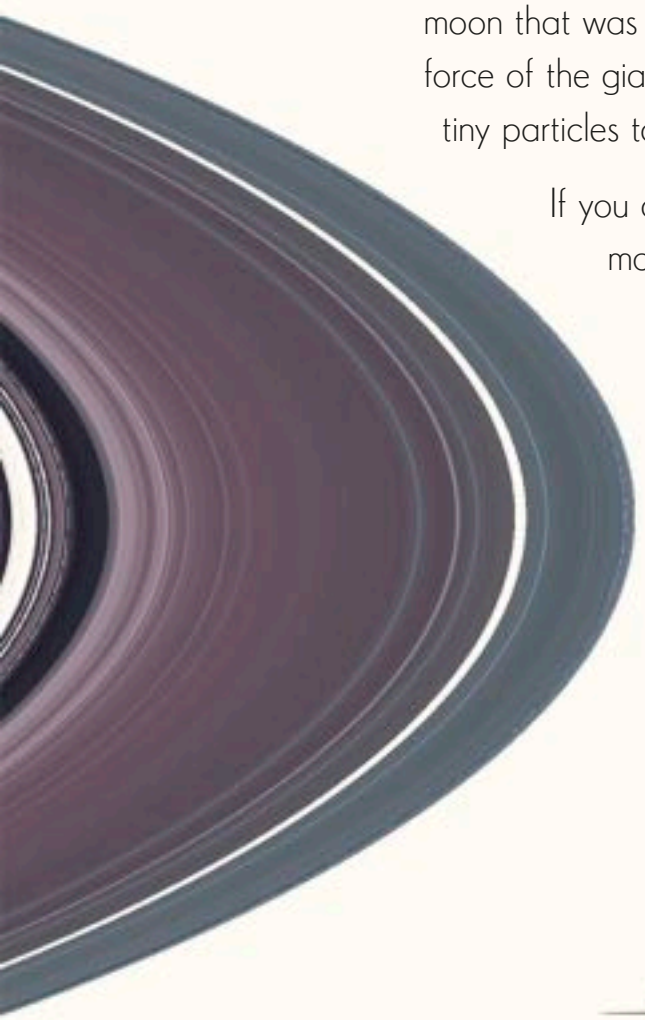
Some of Saturn's moons sculpt the path
of its rings, pushing them into place
with the force of their gravity.

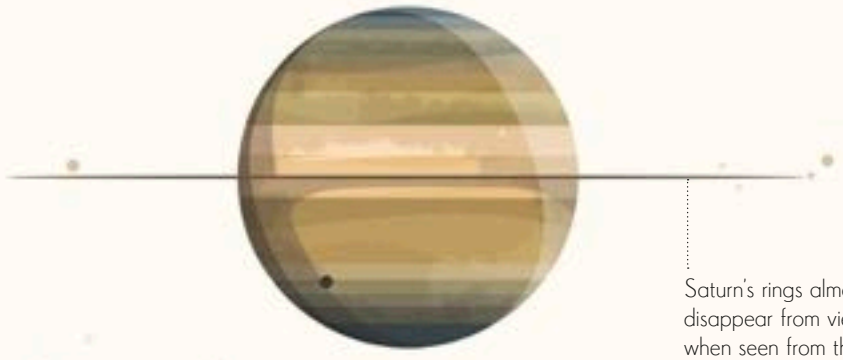


# Rings of ice

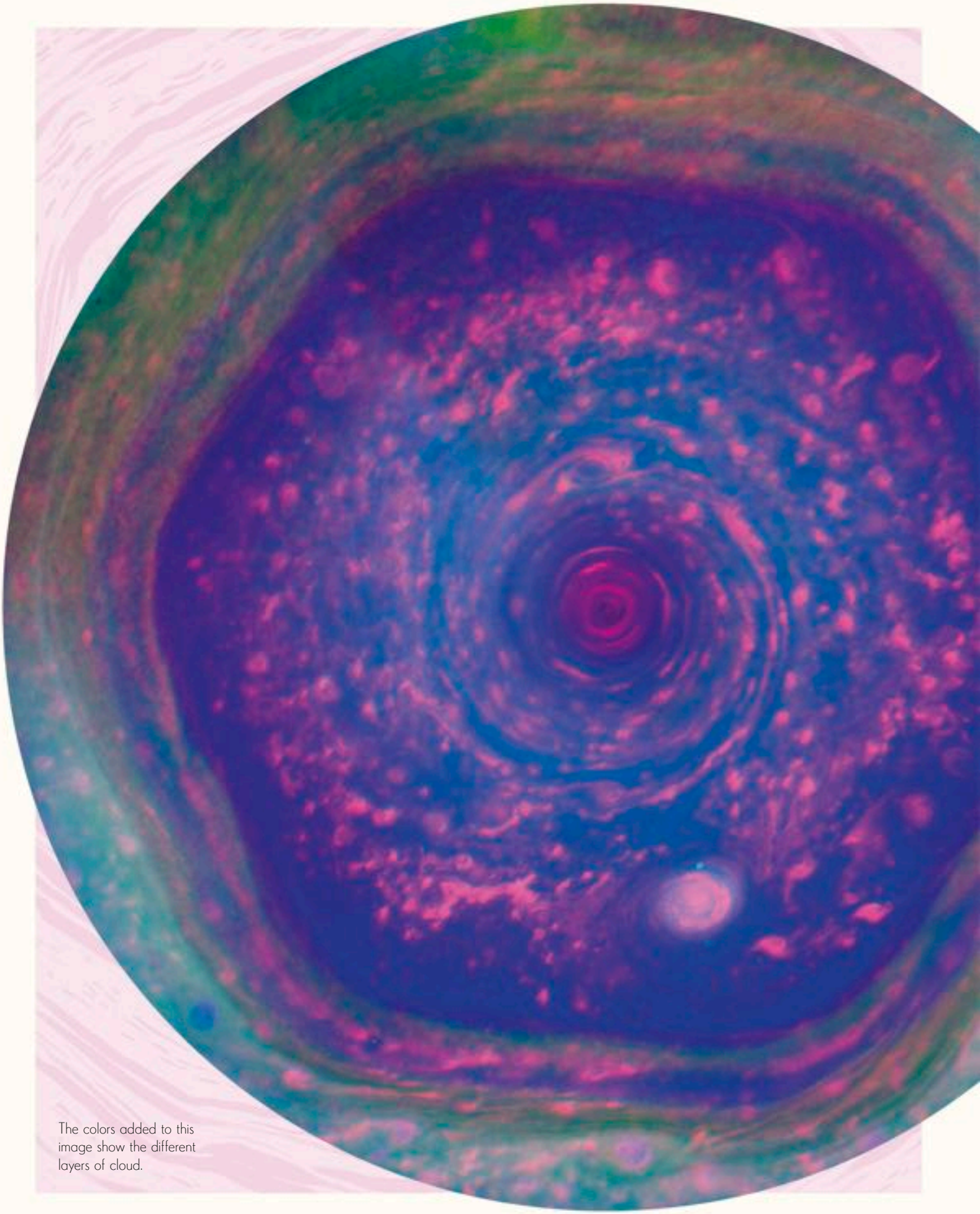
If a fragment of Saturn's magnificent ring system was floating in front of you right now, it would look similar to a clump of snow. Astronomers aren't sure exactly how all these icy chunks ended up circling Saturn. One idea is that they are the remains of a roving moon that was crumbled into pieces by the twisting and pulling force of the giant planet's gravity. The clumps range in size from tiny particles to boulders about the size of a tennis court!

If you could get up close, you would see that the rings are made of a lot of individual streams. Some seem tightly packed together, while others have large spaces between them. Though the main group of rings around Saturn measures about 174,000 miles (280,000 km) across, they're actually incredibly thin—some are only about 33 feet (10 meters) deep.





Saturn's rings almost disappear from view when seen from the side.



The colors added to this image show the different layers of cloud.

# Saturn's polar hexagon

There is a hurricane at the center of Saturn's polar hexagon.

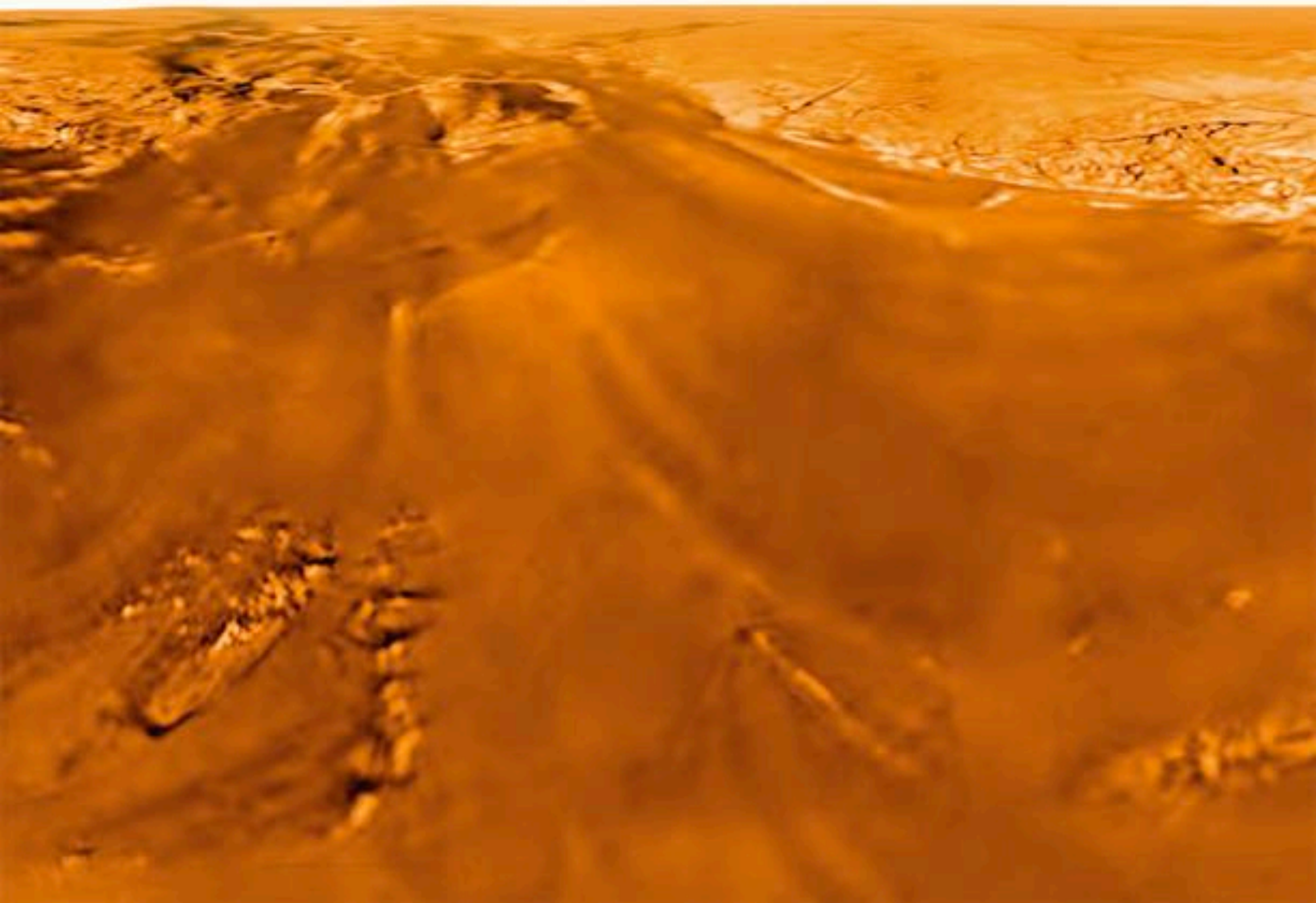
At the very top of Saturn, above its north pole, lies a spectacular shape. It is a pattern of clouds called a polar hexagon—can you see its six sides?

Scientists think that this strange phenomenon is caused by an atmospheric wave. As the clouds move through Saturn's polar skies, this wave guides their flow, a bit like the way a curving riverbed influences the direction of the water above it. Close-up images of the very heart of the six-sided swirl show towering storm clouds spiraling around inside this unusual maelstrom.

You could fit Earth, the moon, and Mars side by side within Saturn's polar hexagon–with room to spare!

# Titan

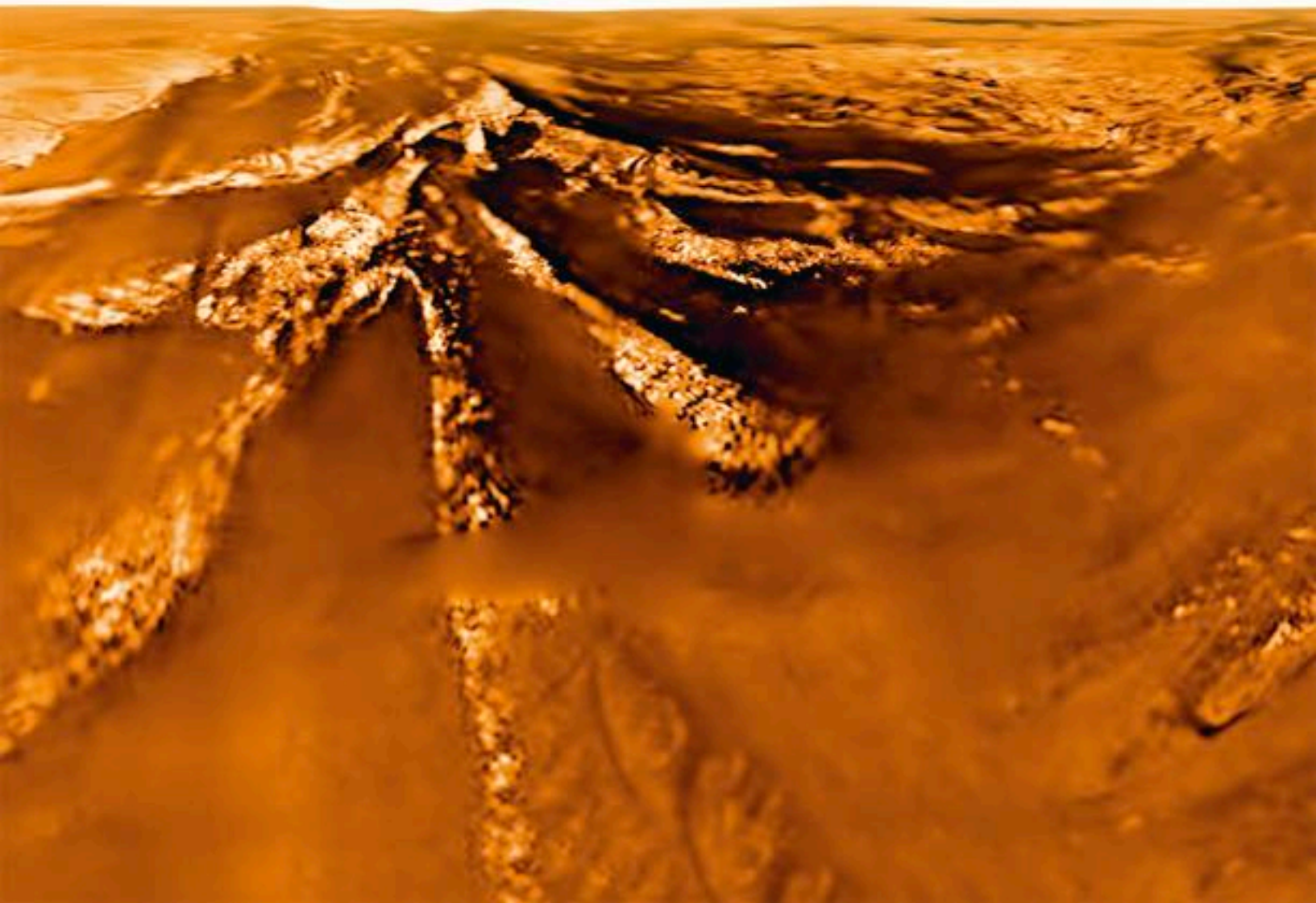
The largest sea on Titan, Kraken Mare, is named after a mythical sea monster.



Titan is Saturn's largest moon. It has a thick atmosphere, made mostly of nitrogen, which hides its surface from view. Below the haze lies a frozen landscape of hills, valleys, and wide-open plains.

On Earth, ethane and methane are usually found in the form of gas, but on Titan the temperatures are so low that these chemicals form as liquid on the surface, and pool into enormous lakes. This liquid is probably responsible for carving out the winding features that look like river channels, which were spotted by the Cassini spacecraft. In 2005, the Huygens probe landed on Titan and sent back pictures of pebbles of ice scattered across its surface.

Titan's surface is rippled with ridges and valleys.



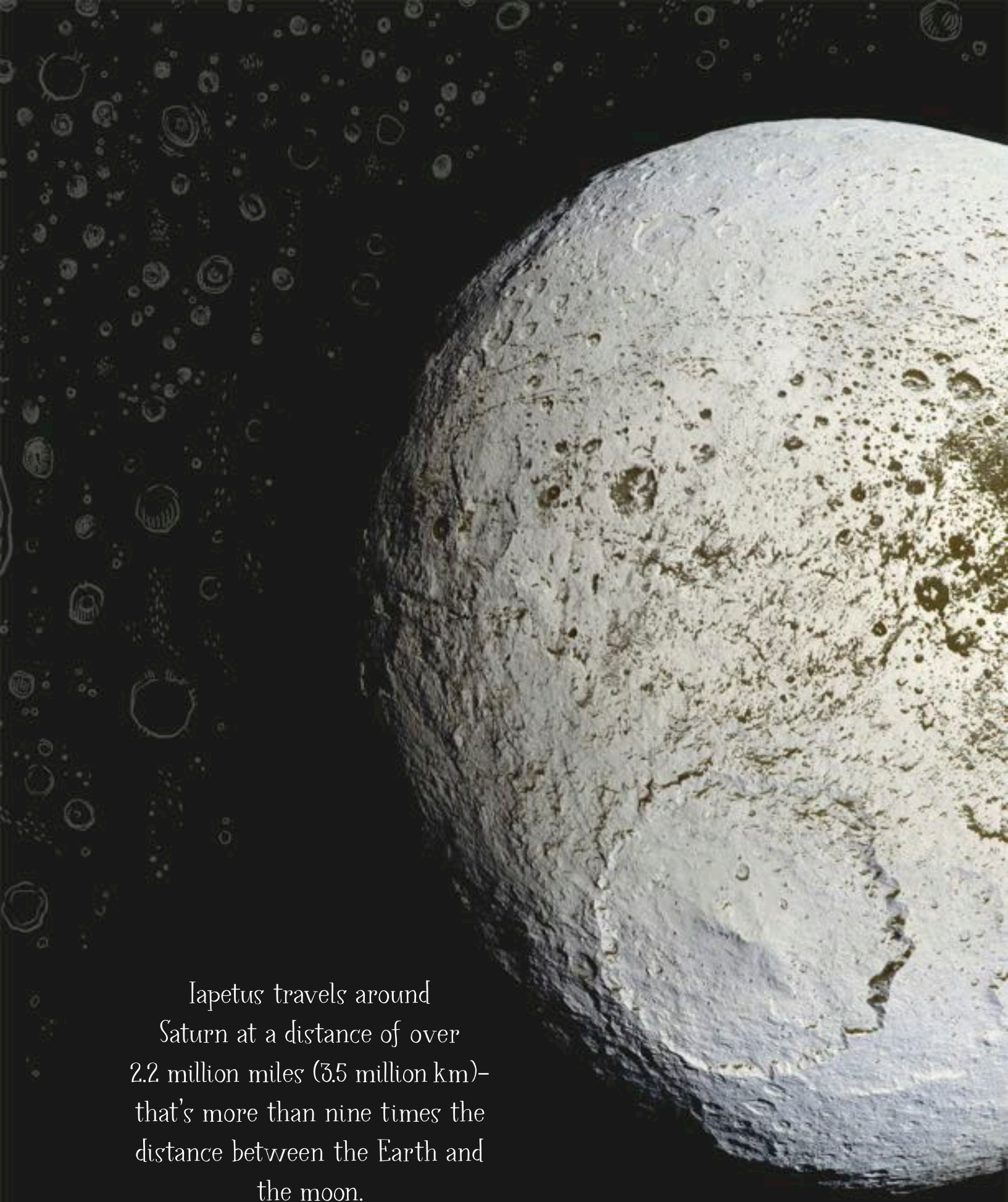
# Enceladus

Enceladus is a white world that looks as if a troupe of giant Rollerbladers has danced all over it. But it's not just a pretty moon—conditions on Enceladus have made scientists very excited as they try to figure out whether life could exist anywhere else in the solar system.

Scientists believe that under the moon's wrinkly surface of ice there's an ocean of liquid water. Its seabed may even be home to hydrothermal vents, where warm water swirls through the rocks. But that is not even the most exciting thing about this distant little moon—as the Cassini spacecraft swooped around Saturn, it spotted huge fountains of icy material shooting out of giant fissures in Enceladus's frozen crust. Could these discoveries mean this moon could support life? We don't know—and we may have to travel there to find out…

The icy grains erupting from Enceladus's fountains form a misty ring around Saturn called the E ring.

Enceladus's icy shell
is white and cracked.



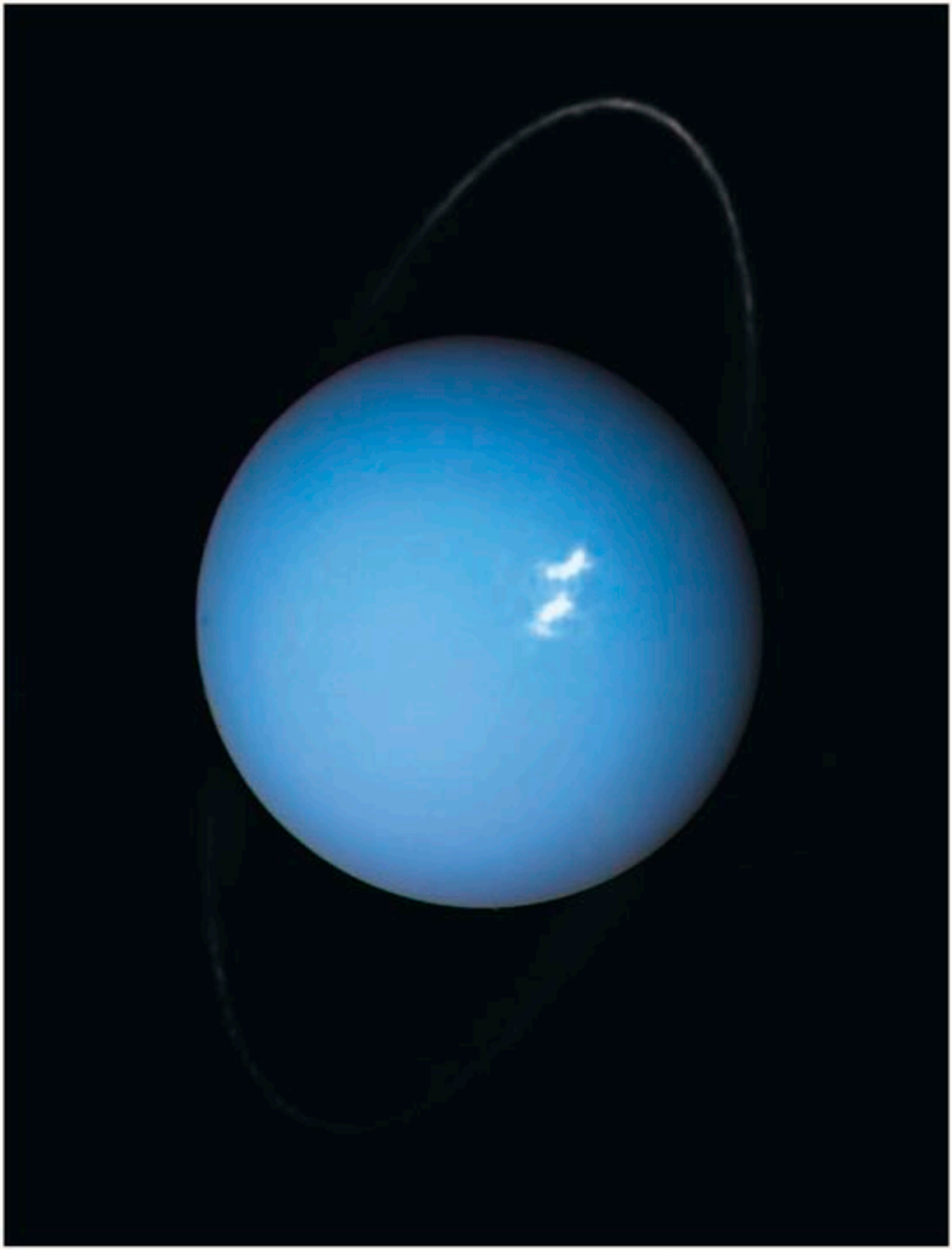
Iapetus travels around Saturn at a distance of over 2.2 million miles (3.5 million km)– that's more than nine times the distance between the Earth and the moon.

Can you spot this moon's bumpy ridge peeking out at its side?

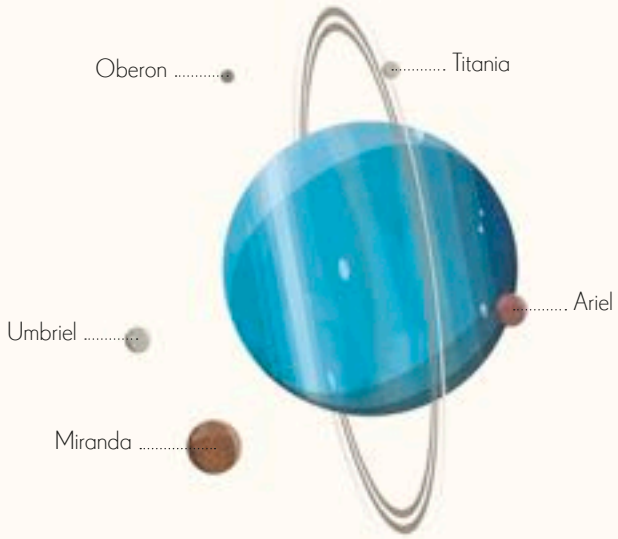
# Iapetus


What do you think could have caused the dark splotches all over the surface of this Saturnian moon, known as Iapteus? If you said they were splattered mud, you're not far from the truth! Scientists think this is dusty material that has fallen onto Iapetus after being blasted off another moon orbiting Saturn, named Phoebe.

Can you see another strange feature of this moon? Around the middle of Iapetus you might spot the unusual ridge that runs part of the way around its equator. It's a mystery how this row of mountains came about—it could have popped up if the moon squashed together after it formed, or if Iapetus was spinning around really fast at some point. It might even be the result of space rocks collecting on the surface!



Uranus has five major moons. Its largest, Miranda, is famous for its huge cliffs– they're several miles high.




# Uranus

Far from the warmth of the sun, Uranus moves slowly through the cold depths of space. It has a ring system and a collection of small moons, but there's something that makes it a bit different from the other planets—its axis is tilted, so it orbits the sun on its side. One possible reason for this is that long ago, the planet was smashed into by another world.

Uranus's atmosphere is mostly composed of hydrogen, helium, and methane. No one knows for sure what lies under its thick blanket of clouds, but it could be a core of ice and rock.

The bright spots you can see here are auroras.

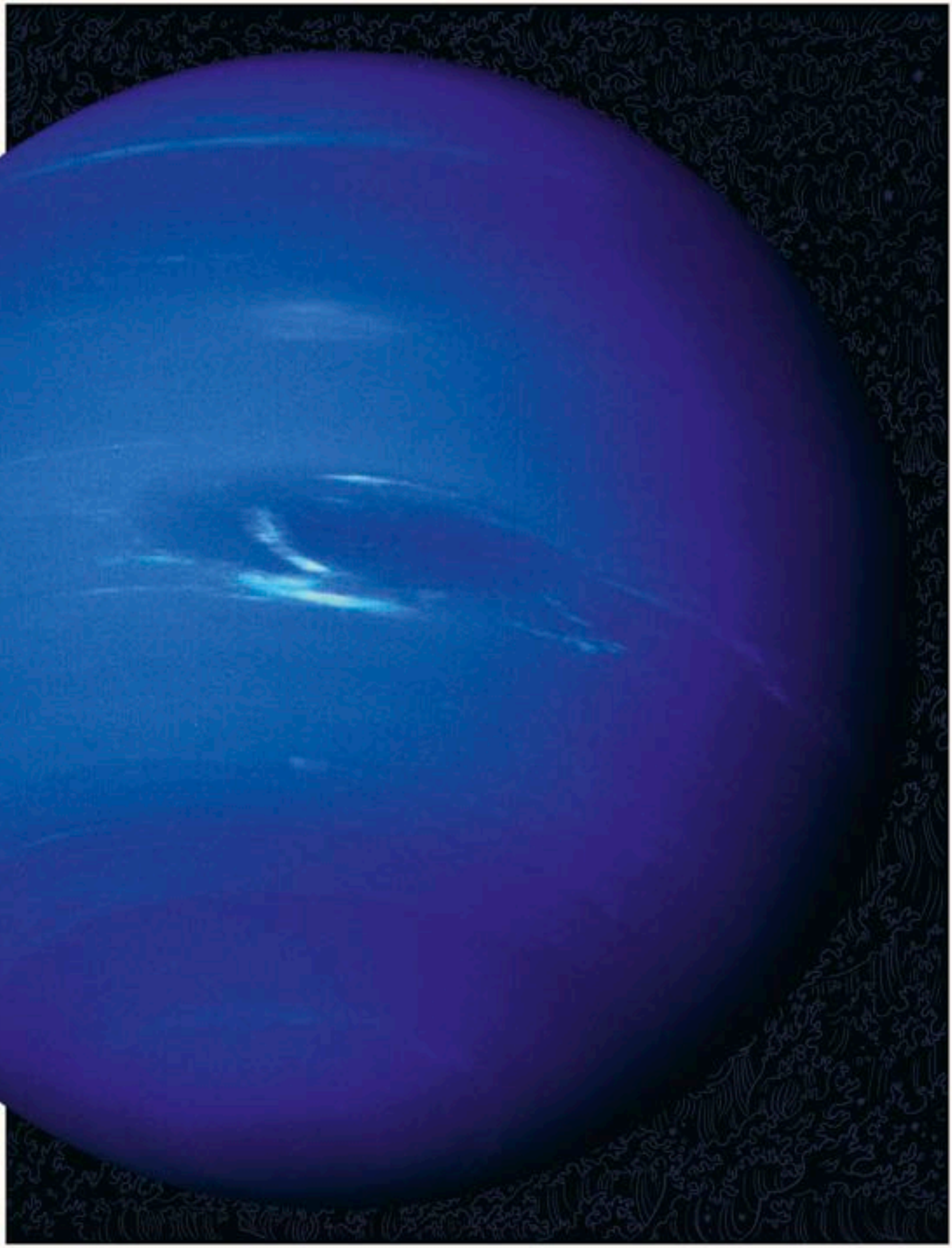
# Neptune


Dark vortexes and bright clouds sometimes appear in Neptune's deep blue atmosphere.

It's difficult to imagine just how far away from the sun the planet Neptune is. It's about 2.8 billion miles (4.5 billion km) away, which means that if you could drive at 50 miles (80 km) per hour through space, it would take you more than 6,000 years to reach it.

At this enormous distance, it takes Neptune 164 Earth years to go all the way around the sun once. Fierce winds whip through the planet's thick atmosphere, which is made up of hydrogen and helium, along with other gases like methane. The tremendous temperatures and pressures inside Neptune make some scientists think that diamonds could be forming and swirling through the planet's hidden depths. Imagine rain made of diamonds!

The Voyager 2 space probe visited Neptune in 1989.



Triton's southern hemisphere

# Triton

Where did Neptune's largest moon, Triton, come from? That might seem like a strange question, but it's one that astronomers have been thinking about for a long time. That's because some scientists believe that Triton may have once floated freely through the outer solar system, before being captured by Neptune's gravity.

Like many of the objects in the distant reaches of our planetary neighborhood, Triton is a cold, icy world. Look closely and you'll see dark smudges in places—it's thought these are streaks left by powerful geysers shooting up plumes of nitrogen from under this moon's frozen surface.

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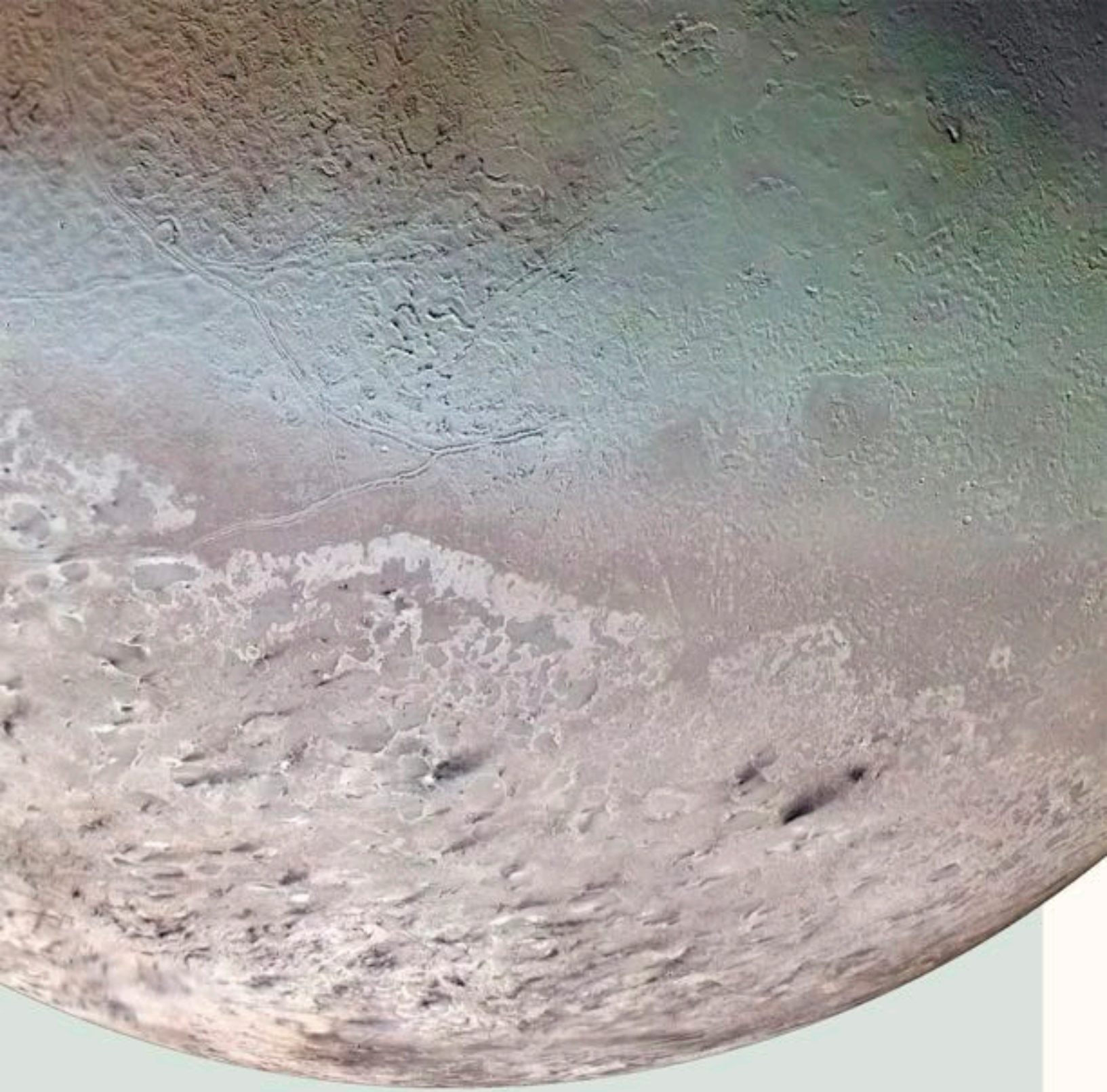
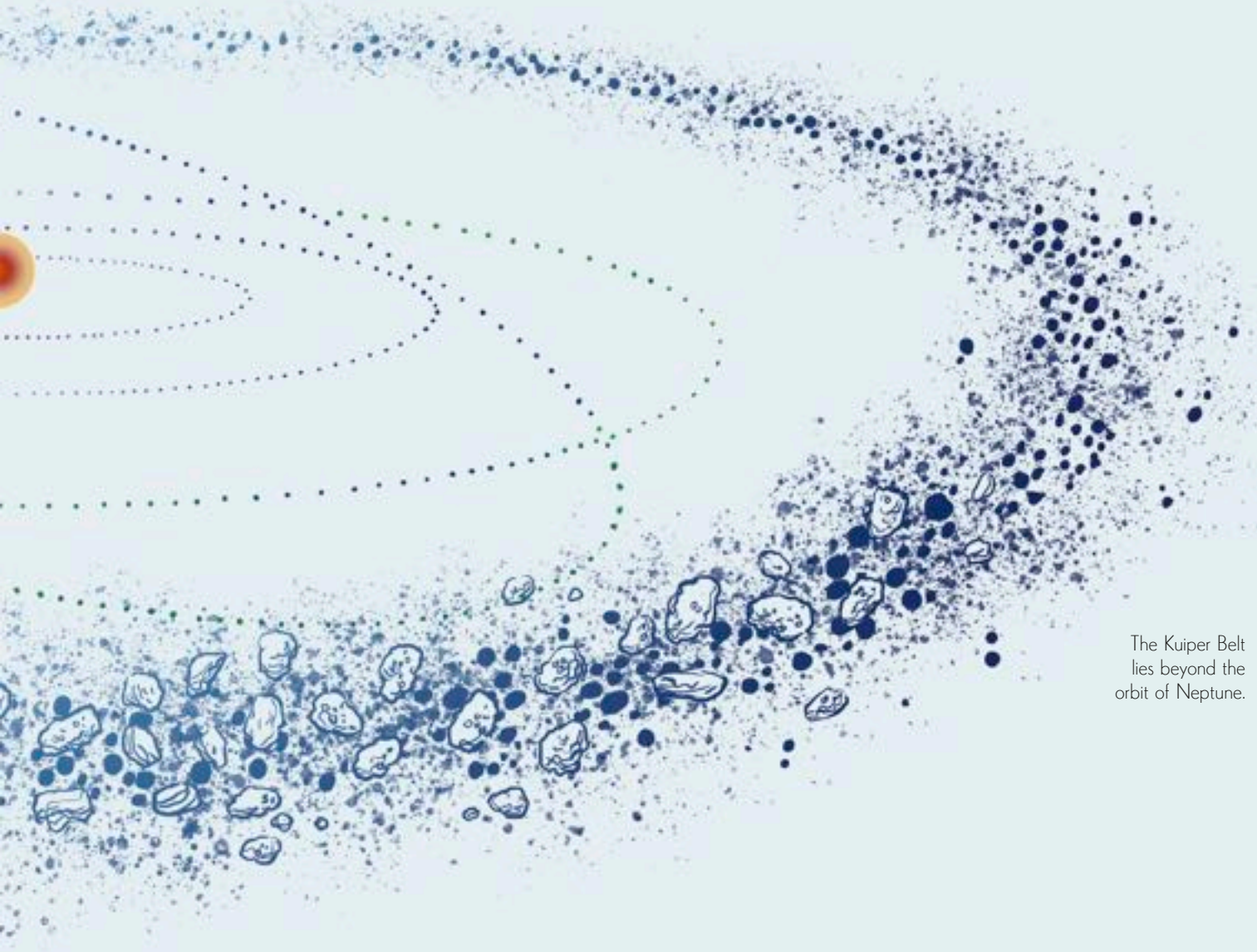


Triton is named after the Greek god of the sea, who was thought to calm stormy waters using his conch shell.

# The Kuiper Belt

The first Kuiper Belt object, after Pluto, was discovered in 1992.



The Kuiper Belt lies beyond the orbit of Neptune.

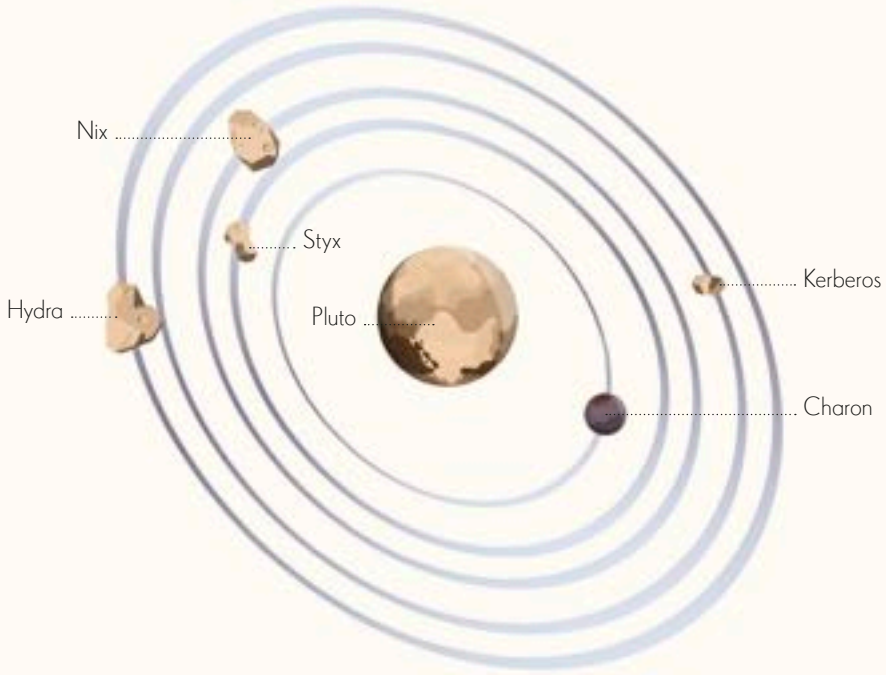
If you travel beyond Neptune you'll eventually reach a gigantic doughnut-shaped region called the Kuiper Belt. It contains thousands of small frozen objects left over from the solar system's early history, and is home to Pluto and three other dwarf planets, Haumea, Eris, and Makemake. Scientists are still piecing together the story of this faraway region. It seems that some of its objects were flung here long ago by the gravity of Neptune and the other gas giants.

The Kuiper Belt is so far from Earth that astronomers use powerful telescopes to study it. Recently, though, a mission called New Horizons explored this region. After many years of traveling, the probe was able to fly past some of the Kuiper Belt's icy treasures.

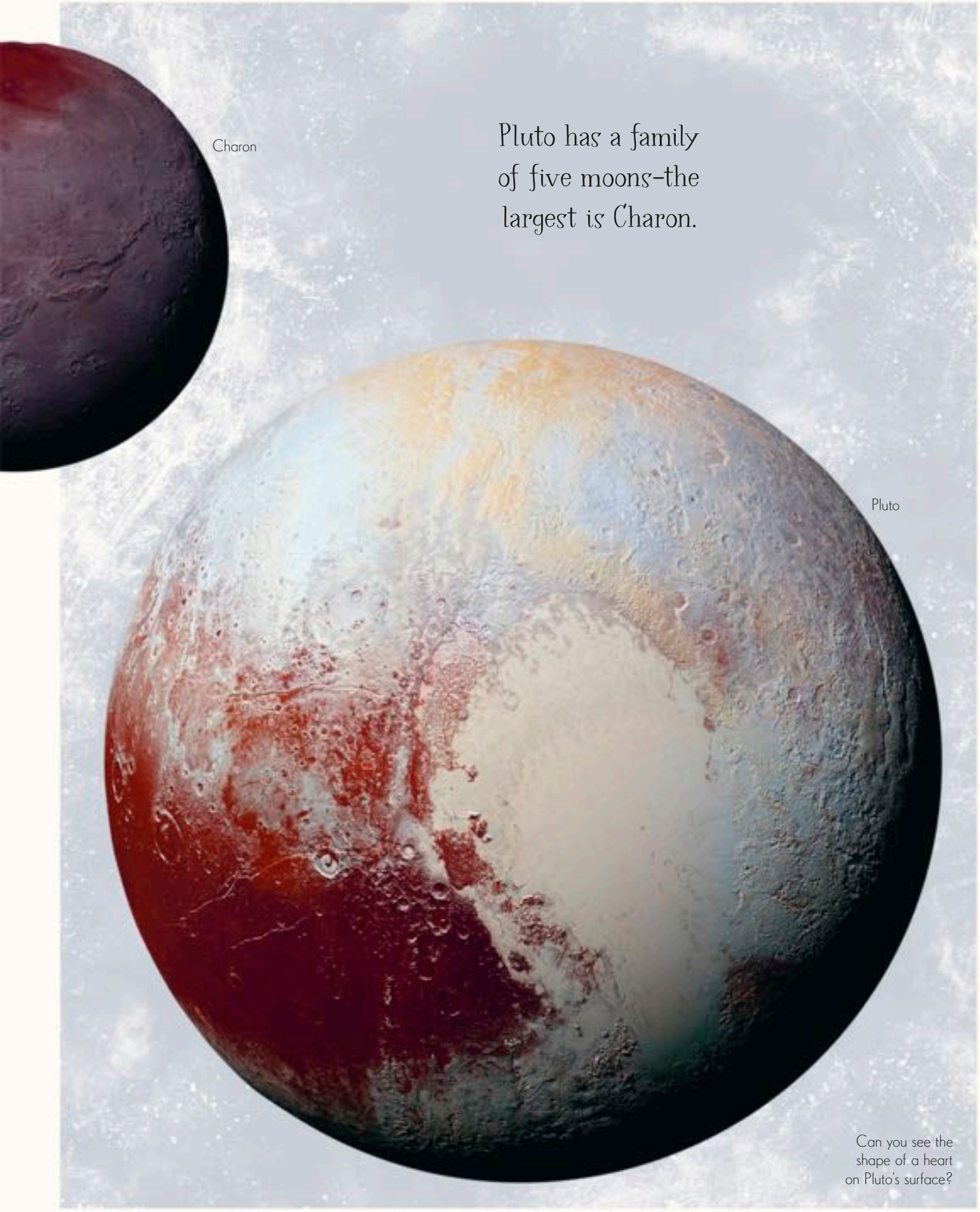
# Pluto

In 1930, American astronomer Clyde Tombaugh was searching through photographs of the night sky, looking for objects hiding in the outer solar system. In one set of pictures he discovered a dot of light moving against the stars. That tiny speck was the world in the Kuiper Belt we now call Pluto.

For a long time everyone thought of Pluto as the ninth planet—the smallest of them all. But new discoveries revealed there were other, similar, icy worlds living in this distant part of our solar system. As our understanding changed, Pluto was put in a new category—we now call it a dwarf planet.




Pluto and its five moons

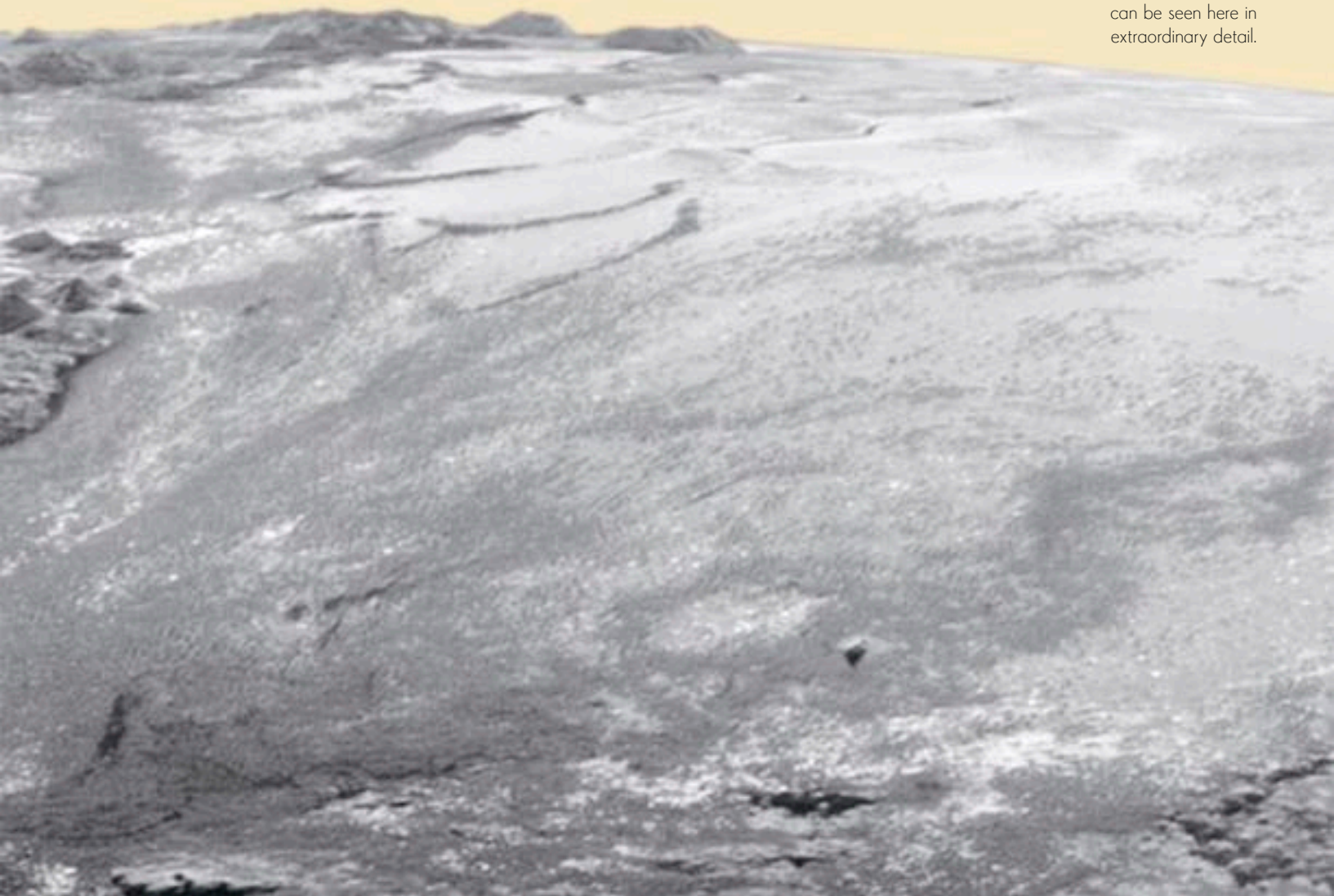

Charon
Pluto has a family of five moons–the largest is Charon.
Pluto
Can you see the shape of a heart on Pluto's surface?

# Frozen fields

Pluto has a thin atmosphere made up of nitrogen, methane, and other gases.

At first glance, you might not think there's anything remarkable about this picture, but it is truly extraordinary. It's not a model from a movie set or a computer-generated image dreamed up by an artist. It's a real picture of the surface of Pluto, captured by a camera on the New Horizons spacecraft.

In this panorama, hills rise up from sweeping plains, while towering mountains and jagged terrain casts shadows in the faint light of the distant sun. But those mountains aren't composed of rock and soil, like the peaks we know on Earth. Instead, they're made of water ice, and the landscape around them is frozen nitrogen.



The mountains and plains of Pluto can be seen here in extraordinary detail.

Arrokoth probably got its shape when two icy objects slowly collided and squashed together.

# An ancient snowman

This peculiar looking object is known as Arrokoth. It lives in the outer solar system, inside the Kuiper Belt. Though it might not look it, it's actually one of the most exciting and important celestial objects that humans have ever visited with a space probe. What makes it so interesting is its great age—it's roughly 4.5 billion years old—and how well preserved it is after billions of years floating in the depths of space. It has survived untouched for all that time, so scientists hope studying it will tell us about how our planetary family formed.

Arrokoth was first spotted in 2014 by the Hubble Space Telescope.

# Comets

Some comets
develop two tails–one
made of gas
and one made of dust.

Comets are the frozen voyagers of the solar system. These lumps of dusty ice usually spend most of their lives in the outer parts of our cosmic neighborhood. Sometimes, though, their long, arcing paths around the sun bring them close to the warmth of our star. As the comet heats up in the sunlight, some of the ice on its surface turns to gas, and it may also start releasing tiny grains of dust into space. When this happens, we can sometimes see the comet as a fuzzy patch in the night sky or—if we're really lucky—a bright, blurry light with a long, glowing tail.

This picture of Comet Hale–Bopp was taken in 1997. The blue streak is the gas tail.

# Cliffs on a comet

Comet 67P

On Comet 67P, also known as Churyumov–Gerasimenko, huge, icy cliffs rise over a frozen landscape covered in boulders. The land is cracked and rugged, and scientists describe the texture of some areas as "goosebumps" and "dinosaur eggs." There are giant pits where jets of gas and dust burst out into the bright sunlight.

We know all this because a European spacecraft named Rosetta traveled to 67P and captured spectacular close-up pictures of its surface. While it circled the comet, Rosetta made important scientific discoveries. From the data it gathered, scientists are hoping to learn more about how comets could have helped make planets like Earth.

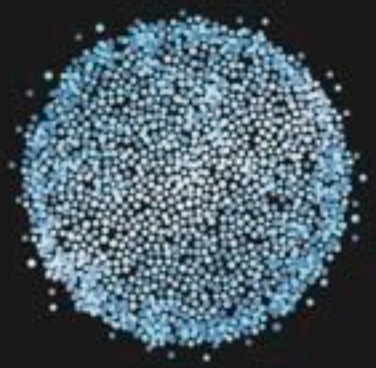
Some of the cliffs on Comet 67P are several hundred meters high.

Cliffs of ice and dust, as seen by the Rosetta spacecraft

Scientists use computer models to figure out the size and shape of the Oort Cloud.

Some scientists think there could be well over a trillion objects in the Oort Cloud.

# The Oort Cloud



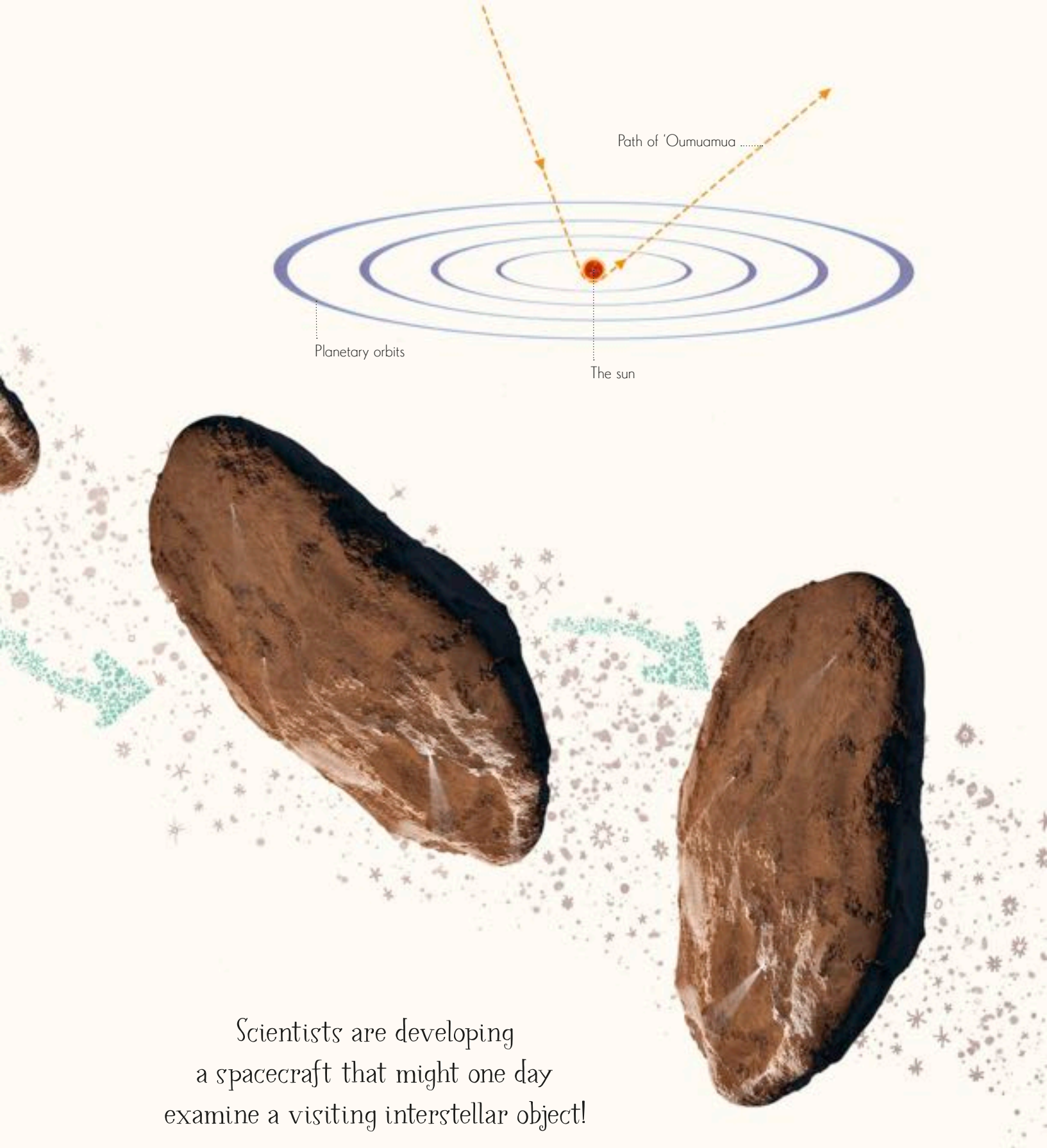
Did you know there's a feature of our planetary neighborhood that no one has ever seen? It's called the Oort Cloud, but it's nothing like the fluffy white wisps that float across our blue skies. It's thought to be a huge swarm of cometlike objects that surrounds the solar system. It's incredibly far away—parts of it are thousands of times farther from Earth than the most distant planet, Neptune. So why do astronomers think the Oort Cloud is out there if they've never actually seen it? One reason is that comets sometimes arrive in the inner solar system that seem to have come from this remote region. Scientists think there must be many more lurking out there to explain these well-traveled wanderers.

'Oumuamua tumbles through space, spinning once roughly every seven hours.

# Interstellar visitors

In the last few years, astronomers have come face to face with the first-known visitors from distant star systems beyond the sun's realm. These two alien travelers weren't the kind you might imagine from sci-fi movies, though. Instead, they were an asteroid and a comet that must have been flung from their faraway home system long ago.

The asteroid, called 'Oumuamua (oh-MOO-ah-MOO-ah), was seen zipping through our solar system in 2017, while the comet, Borisov, was spotted in 2019. Astronomers raced to study the two interstellar objects before they zoomed away forever, in the hope of learning more about the mysterious places from which they came.




Scientists are developing
a spacecraft that might one day
examine a visiting interstellar object!

Scientists think the Milky Way contains around 200-400 billion stars.

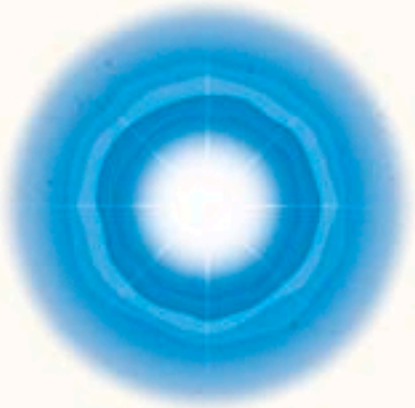
# The Milky Way

Our sun is one of billions of stars that swirl through space in an enormous gathering known as a galaxy. We call this home galaxy of ours the Milky Way. That's because from our perspective—sitting among this huge swarm of stars—the rest of the galaxy looks like a milky, misty ribbon of light.

If you could fly away from the Milky Way and look back, you would see that the galaxy is shaped like a disk with a ball-shaped center. Within this disk there are whirl-like structures called spiral arms—we live inside one of these.

NASA telescopes use infrared and X-ray light to reveal the beauty of the Milky Way.

# Stars



Every night, the sky glitters with the light of countless twinkling stars. They appear as tiny points to us only because they are so far away. If we could travel to explore them up close we'd see that they are, like our sun, blazing balls that shine as matter fuses, or joins together, inside them.

Since the stars are so distant, it takes a long time for their light to reach us. For example, the light we see now from the middle star in Orion's Belt, Alnilam, started its journey almost 2,000 years ago. When you look at the sparkling night sky, you're actually gazing deep into the past. Isn't that amazing?

Stars can have life spans of billions of years!

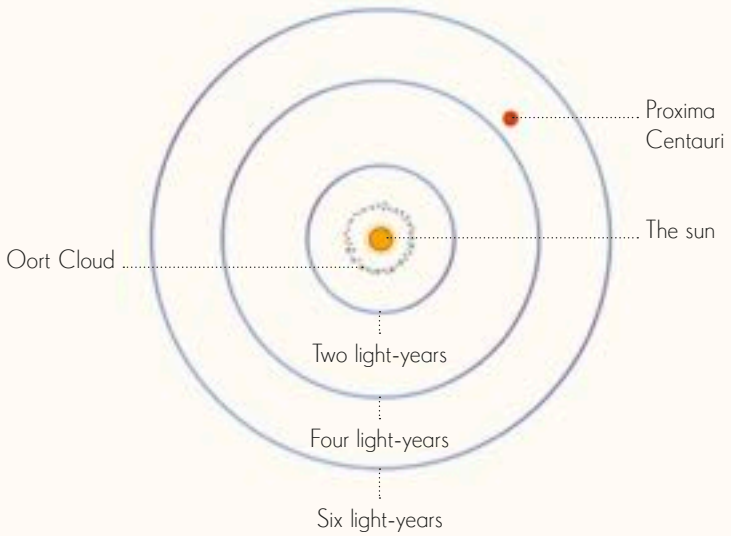
This group of stars was photographed by the Hubble Space Telescope.

In 2016, astronomers discovered a planet orbiting Proxima Centauri.

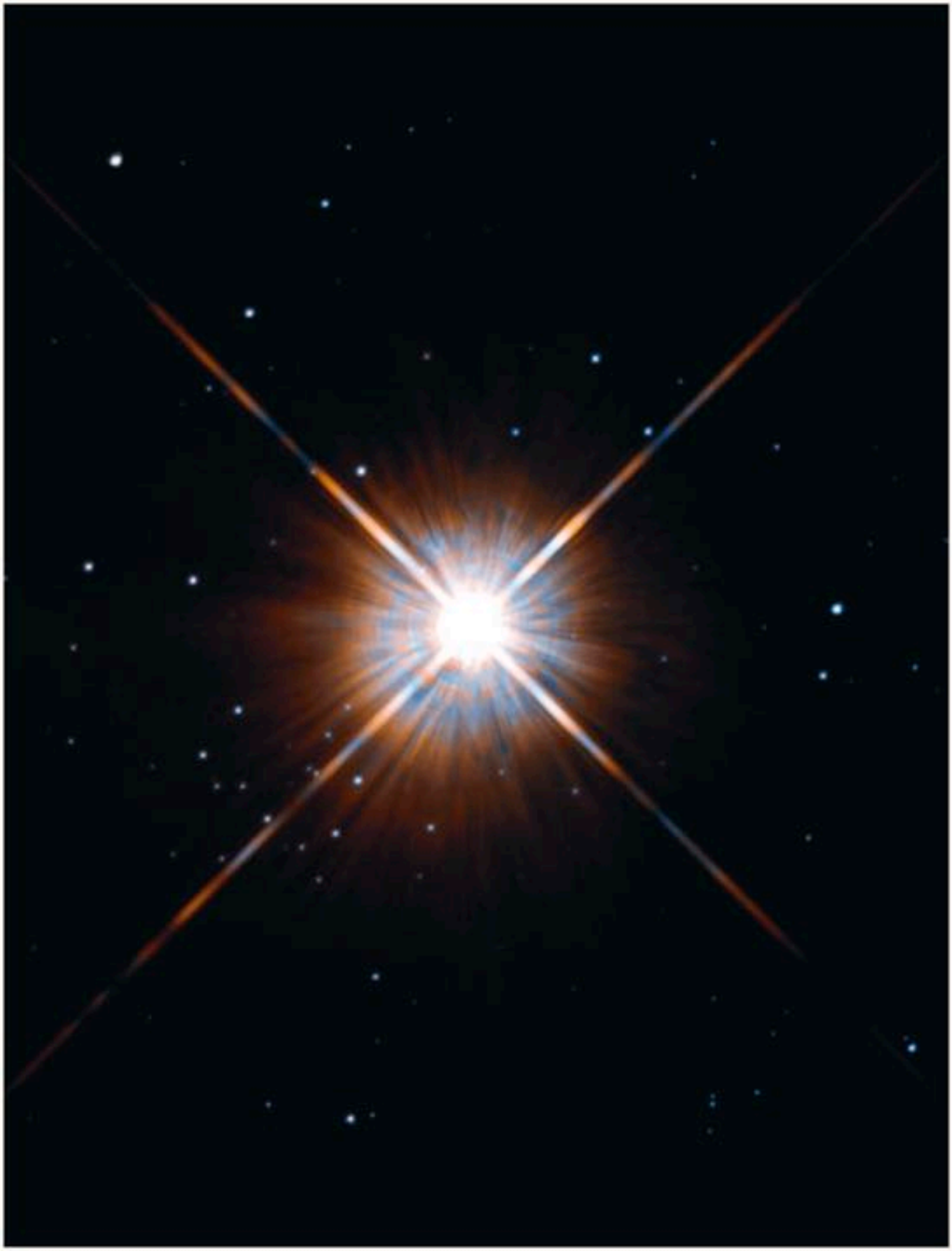
# Proxima Centauri

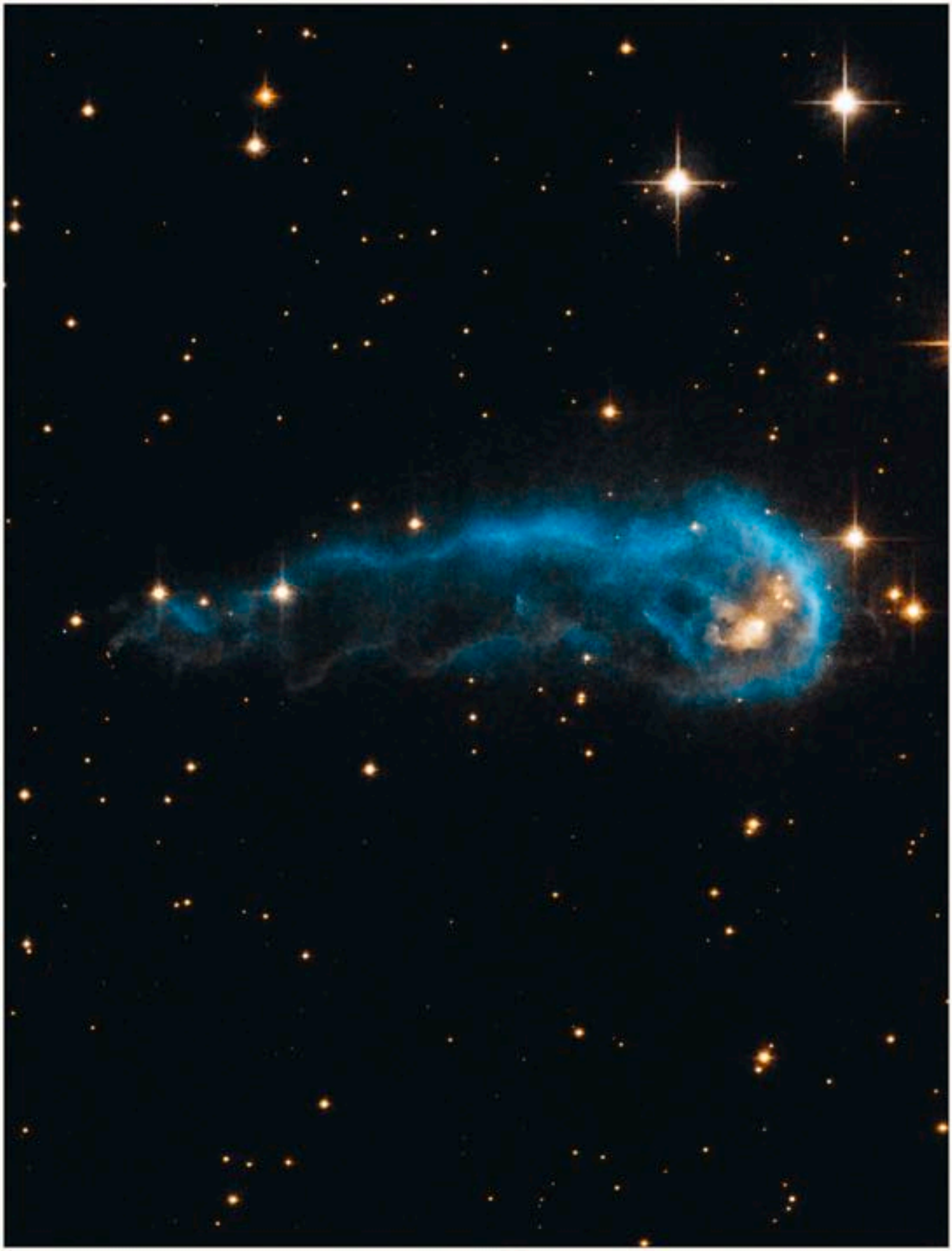
Where the pale band of the Milky Way runs through the Southern Hemisphere constellation of Centaurus, the night sky is brimming with stars. Nestled among these gems is a faint red star called Proxima Centauri.

Though you'd need a good telescope to see it, this little fleck of light is quite special—at about four light-years away, Proxima Centauri is the closest star to the sun. It is still a huge distance from us, though—if the sun was the size of the tip of a pen, then Proxima Centauri would be nearly 18 miles (29 km) away!




This image of Proxima Centauri was captured by the Hubble Space Telescope.





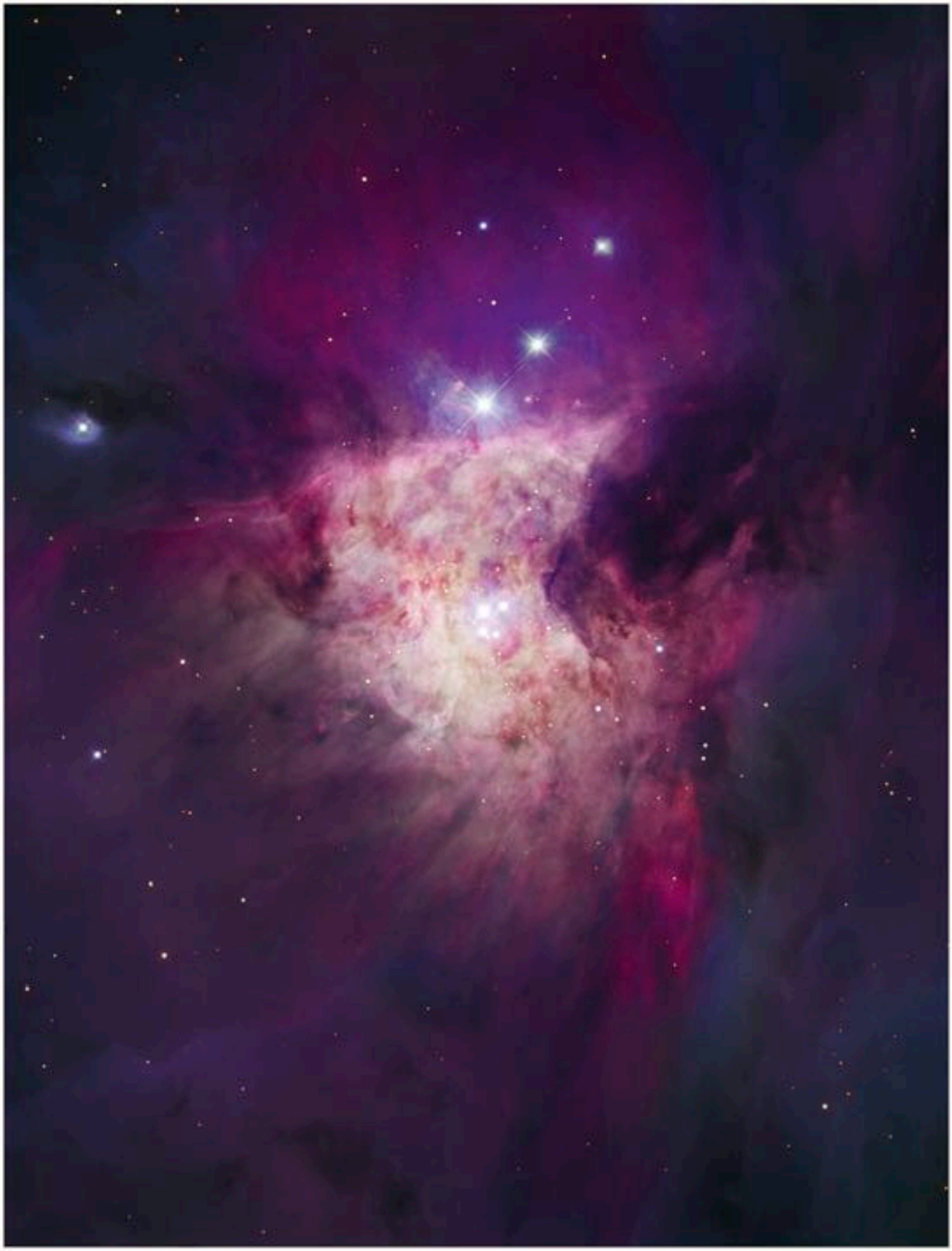
Enormous jets of material sometimes shoot out from protostars, like beams from a lighthouse.

# The youngest stars

Stars are born within enormous clouds of gas and dust floating in space. Astronomers think the process begins when clumps start to form deep inside the cold, dark haze. Over time, the clumps grow as they gather material from around them—a bit like how a snowball gets bigger. Eventually, a spinning object known as a protostar forms. If it grows large enough, nuclear reactions can fire up within a protostar's center and it becomes a fully fledged, shining sun.

Scientists still have a lot of questions about exactly how all this happens. This is partly because baby stars are often hidden by the dusty gas clouds in which they are born—to investigate, astronomers need special telescopes and cameras to peer through the murk.

This protostar is gathering material from the gas surrounding it.



# The Trapezium Cluster

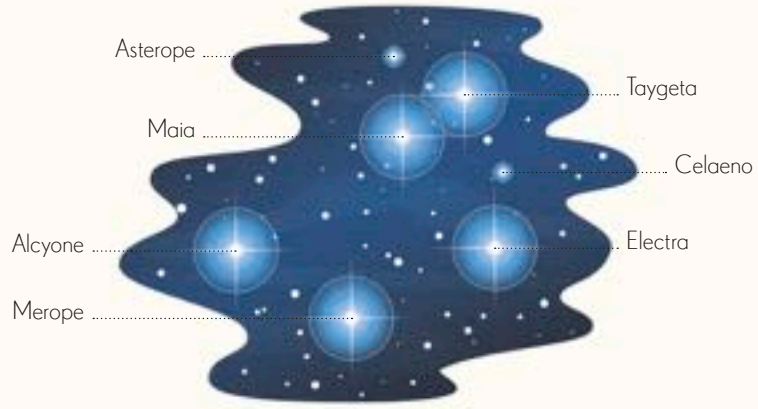
What do you think is causing these swirling gas clouds to glow such a beautiful ruby-red color? Look at the very center of the view, where the clouds are brightest, and you'll see the culprits: a group of four sparkling newborn stars. This little collection is known as the Trapezium Cluster, and it lies nestled in the heart of the Orion Nebula.

The stars in the Trapezium are scorching hot and they blaze brightly. Their light energizes the gas around them, causing it to give off a pinkish-red glow. Curiosities like the Trapezium Cluster are fascinating to astronomers because by studying them we can learn more about the early lives of stars and the groups they form.

You can spot the Trapezium Cluster from Earth using a small telescope.


The heart of the Orion Nebula

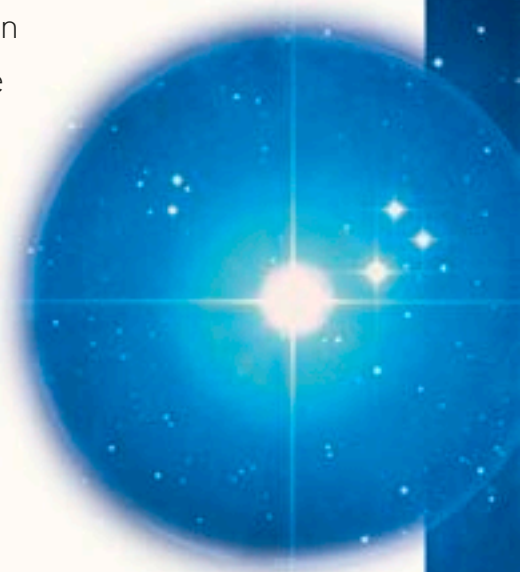
Can you see the cluster in the center of the nebula?




# Star clusters

When you gaze up at the night sky, you'll see little groups of stars huddled together. Astronomers call these groups star clusters. Some of the easiest to see are open star clusters—collections of bright young stars that have formed together in space.

The Pleiades is a famous open star cluster that sits in the constellation of Taurus, the Bull. There are more than 1,200 infant stars in this dazzling crowd. Recent measurements suggest that the stars in the Pleiades are only around 130 million years old!

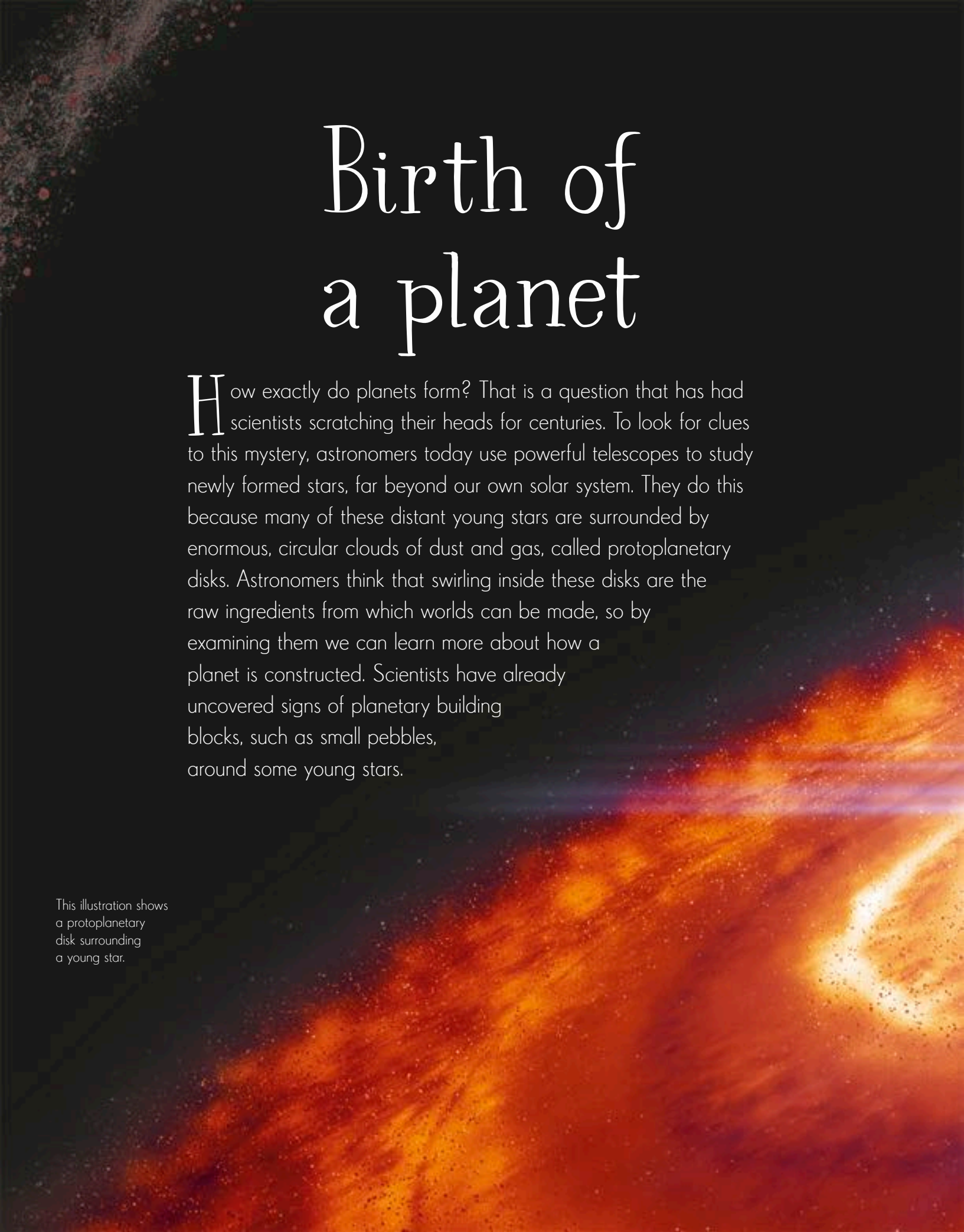


Our sun probably formed within a cluster of stars that has now spread out across the Milky Way.

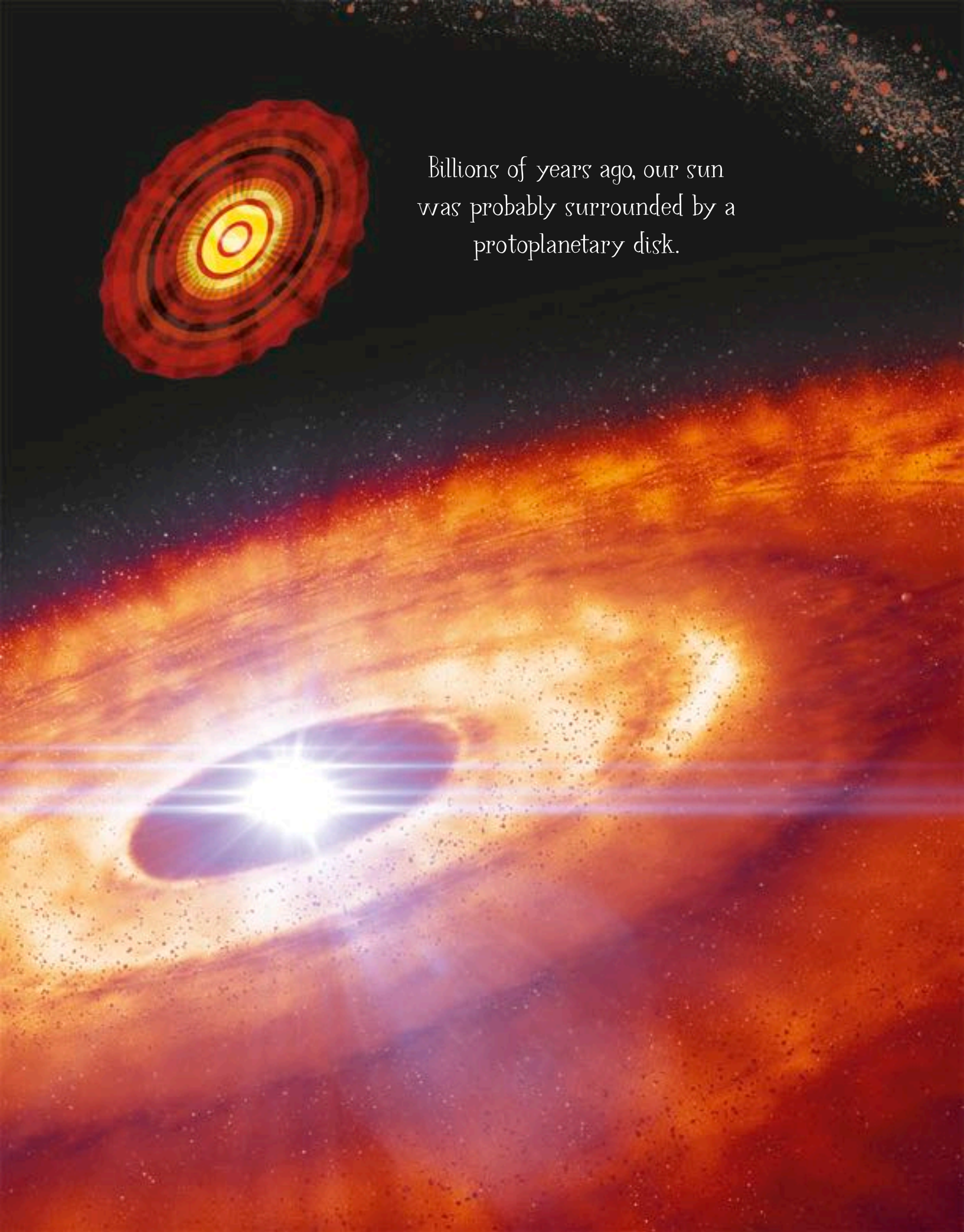
The Pleiades is also known as the Seven Sisters.

# Birth of a planet

How exactly do planets form? That is a question that has had scientists scratching their heads for centuries. To look for clues to this mystery, astronomers today use powerful telescopes to study newly formed stars, far beyond our own solar system. They do this because many of these distant young stars are surrounded by enormous, circular clouds of dust and gas, called protoplanetary disks. Astronomers think that swirling inside these disks are the raw ingredients from which worlds can be made, so by examining them we can learn more about how a planet is constructed. Scientists have already uncovered signs of planetary building blocks, such as small pebbles, around some young stars.



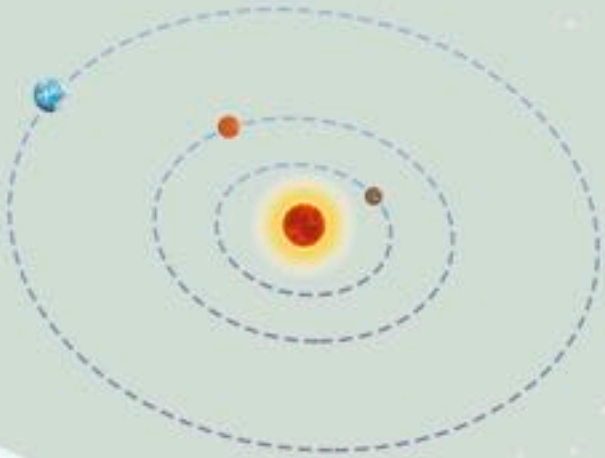
This illustration shows a protoplanetary disk surrounding a young star.



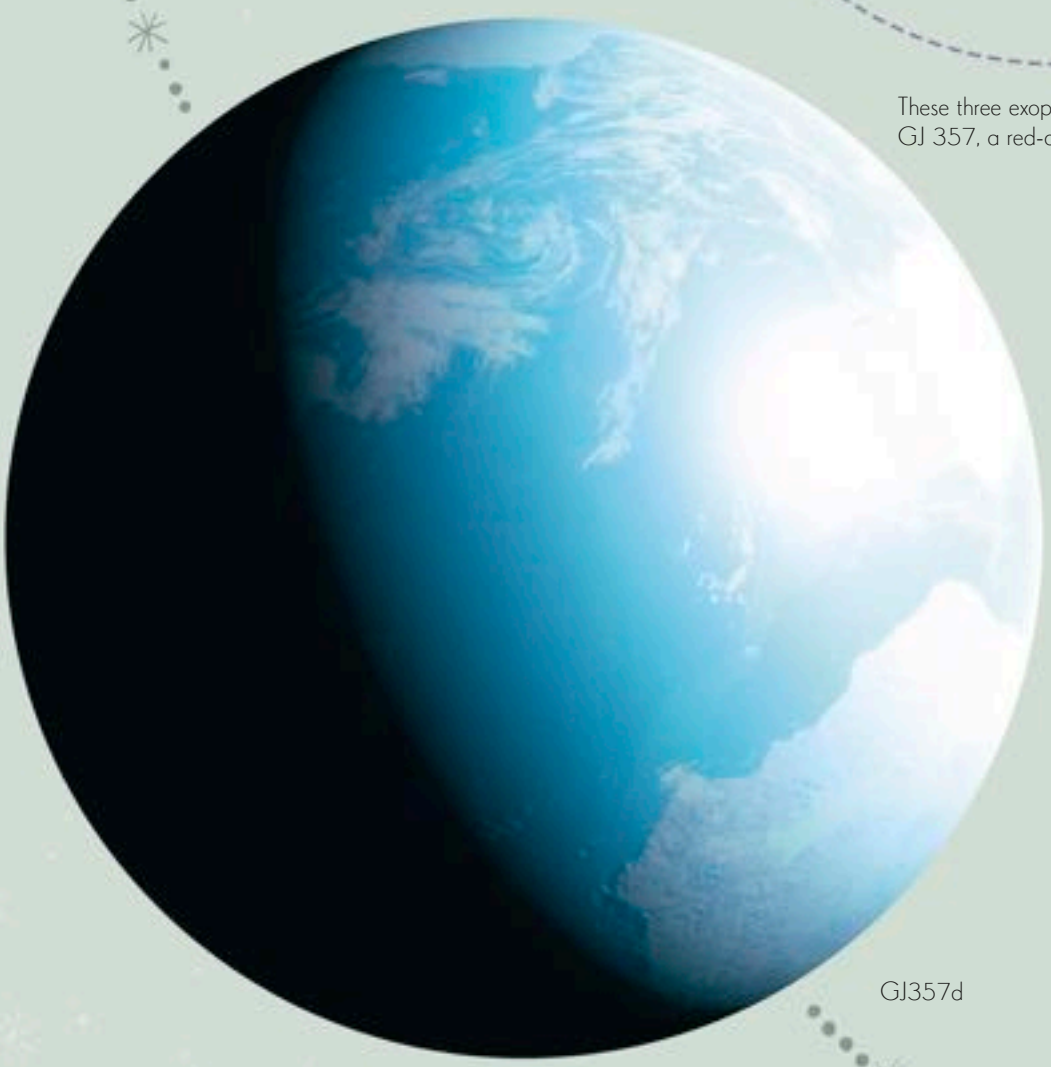
Billions of years ago, our sun
was probably surrounded by a
protoplanetary disk.

# Exoplanets

So far, more than 4,000 exoplanets have been found orbiting around distant stars.



These three exoplanets orbit GJ 357, a red-dwarf star.



GJ357d

GJ357c

GJ357b

While we don't know if there are other life forms elsewhere in the Milky Way, we do know there are other planets out there. Thousands of them, in fact! These worlds are known as exoplanets.

There is still a lot about exoplanets that we don't know. Many of them seem to be very strange places indeed. Some could have bubbling surfaces of molten rock, while others have ferocious winds that race around their atmosphere. Some are giant worlds made of gas that orbit close to their fiery parent star—we don't have anything like that in our solar system. In the coming decades, new telescopes should allow us to take a closer look at some of these faraway planets. Perhaps we'll even find one just like Earth!

# Vega

The light we see today from Vega left the star's surface about 25 years ago.


Vega is one of the brightest stars in the night sky. It lies in the constellation Lyra, close to the rich star fields of the Milky Way. If you cast your eyes toward this brilliant star on a clear fall night in the Northern Hemisphere, you'll see it has a white hue, with a slight hint of blue. Gaze around and you'll soon see stars of other colors too—some orange, some yellow, others zingy blue.

Why are stars different colors? It all depends on their temperature. The hotter a star is, the bluer and whiter its light—cooler stars are more yellow and orange. Some of the coolest stars in the galaxy have a deep red-orange glow, like embers in a fireplace.

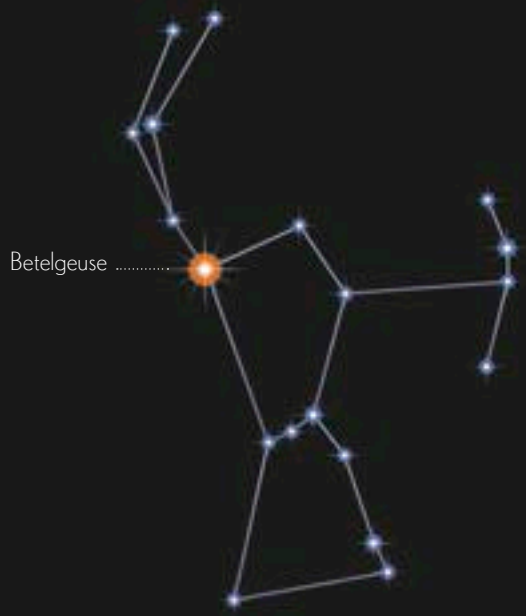
Vega was the very first star—after our own sun—to be photographed in 1850.

Betelgeuse is about 720 light-years away from Earth.

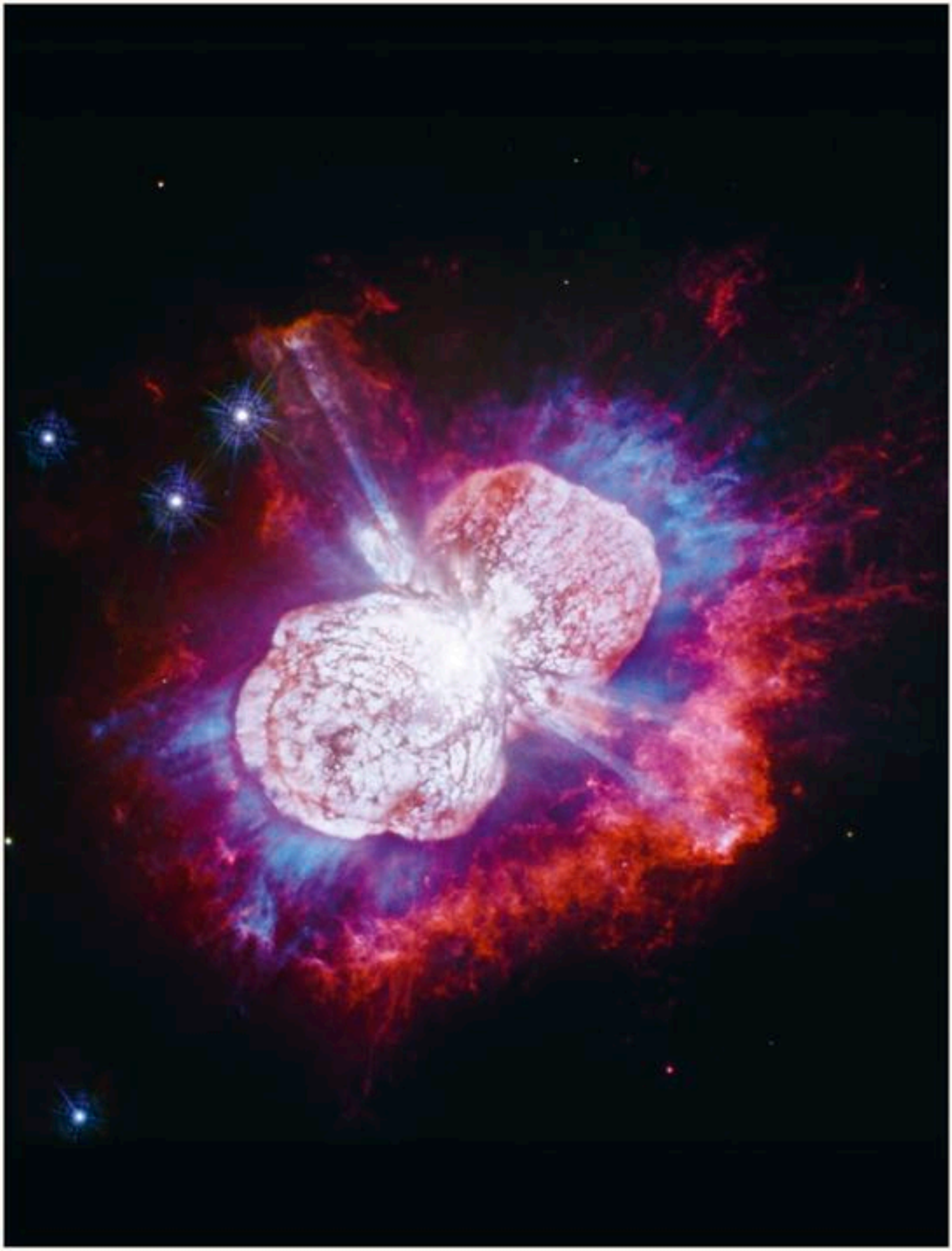
You could squeeze about 900 trillion Earths inside Betelgeuse!

# Betelgeuse

One of the most mysterious stars in the constellation Orion is the red-hued Betelgeuse. It is in the very final stages of its life. After consuming much of its fuel, it has bloated to become a vast, red supergiant measuring more than 746 million miles (1.2 billion km) across. If the sun was the size of a pea, Betelgeuse would be over 23 feet (7 meters) wide! When it dies, Betelgeuse will likely explode as a brilliant supernova. Astronomers aren't sure exactly when this will happen, but some estimates suggest it could detonate in the next 100,000 years.




Orion constellation



# Eta Carinae


You wouldn't know it if you looked at the softly shimmering star fields in the constellation Carina, but this stretch of the Southern Hemisphere night sky is full of violent activity. Within Carina there is an incredible stellar system called Eta Carinae, which is composed of two stars. The reason it is so fascinating is that one of the pair has recently experienced unimaginably huge eruptions. Scientists think it is probably close to the end of its life.

Eta Carinae is surrounded by a peanut-shaped cloud of material and glowing wisps of gas—these were probably created during previous explosions of the dying star. Eventually, Eta Carinae will detonate in one final, enormous, explosion, called a supernova. As it does, it will shoot material out into space that may one day form the beginnings of a new generation of stars.

Eta Carinae is so far away that the events we see today actually happened over 8,400 years ago.

Eta Carinae exploded several times in the 19th century.

The most famous supernova of recent times, SN1987A, occurred within a nearby galaxy in 1987.

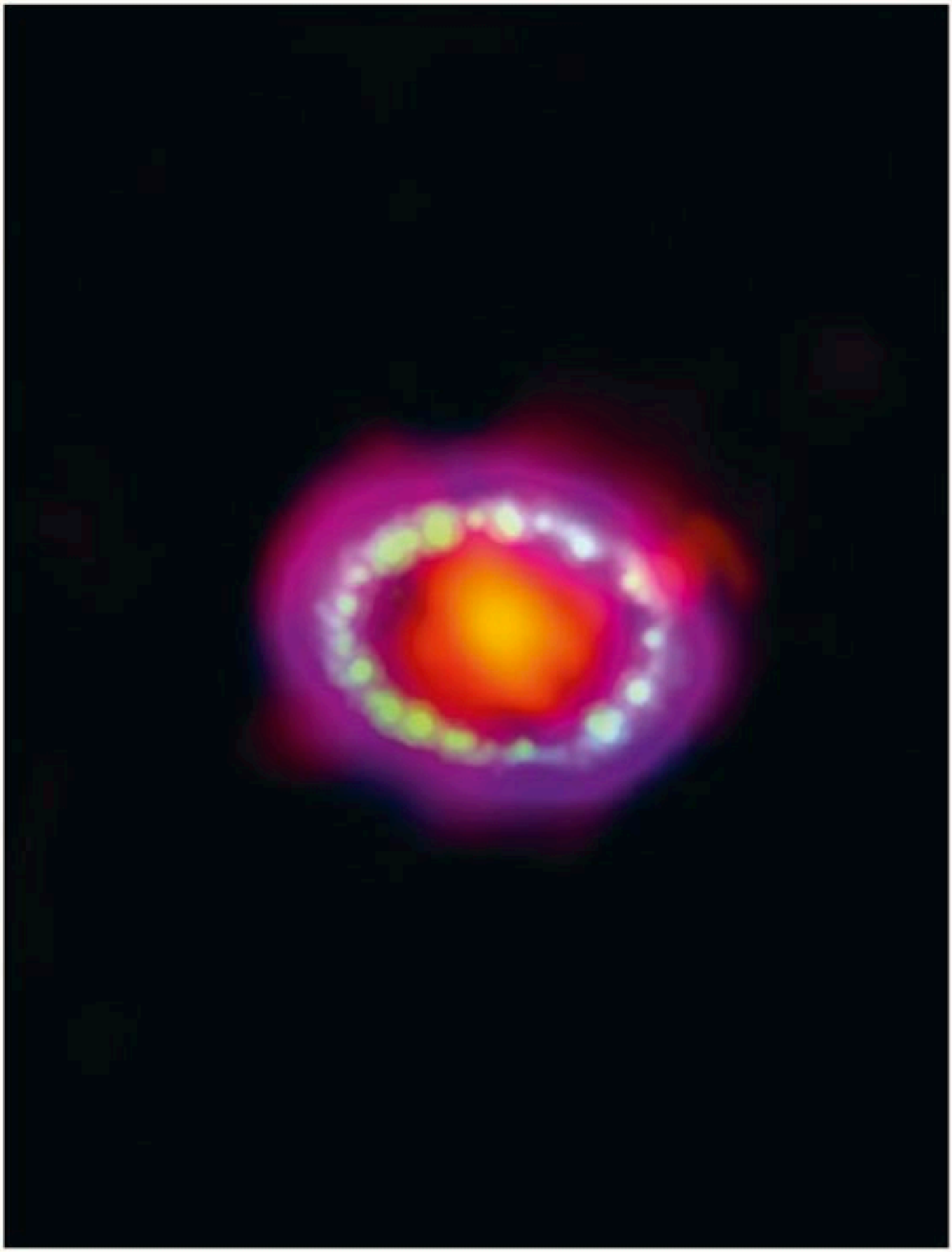
# Supernova

Sometimes a star can explode in a violent blast that astronomers call a supernova. These spectacular events can occur in different ways. One type of supernova happens when a massive star gets old and runs out of the fuel that keeps it shining. When this happens, its center implodes, producing an explosion that destroys the star.

Another kind of supernova occurs when the core of a long-dead star, known as a white dwarf, rips chunks of the atmosphere from a nearby star. If the white dwarf pulls enough material onto itself, it can explode, creating an enormous stellar firework that can be seen across huge cosmic distances.

Supernova

The colors in this picture highlight the shock wave and dust ring in the aftermath of SN1987A.

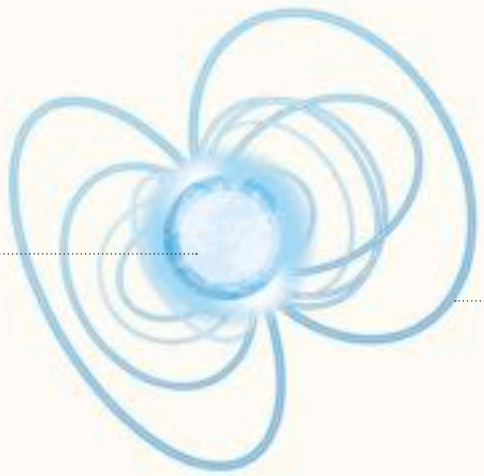


Neutron stars are typically only about 12 miles (20 km) in diameter.

# Neutron star

Neutron stars are the zombies of interstellar space. These amazing objects are created in the fiery explosion that occurs at the end of a massive star's life. Neutron stars are made up of a superdense material consisting of tiny subatomic particles called neutrons. A grain-of-sand-sized fleck of neutron star matter would weigh roughly 550,000 tons (500 million kg)—about the same as 1,500 jumbo jets put together.

Some neutron stars blast beams of radio waves out across space. If the beams pass over Earth, as the neutron star spins, we can detect a throbbing radio signal. Astronomers call these objects "pulsars."




Can you see the two bright spots in the center? The neutron star is the one on the right.

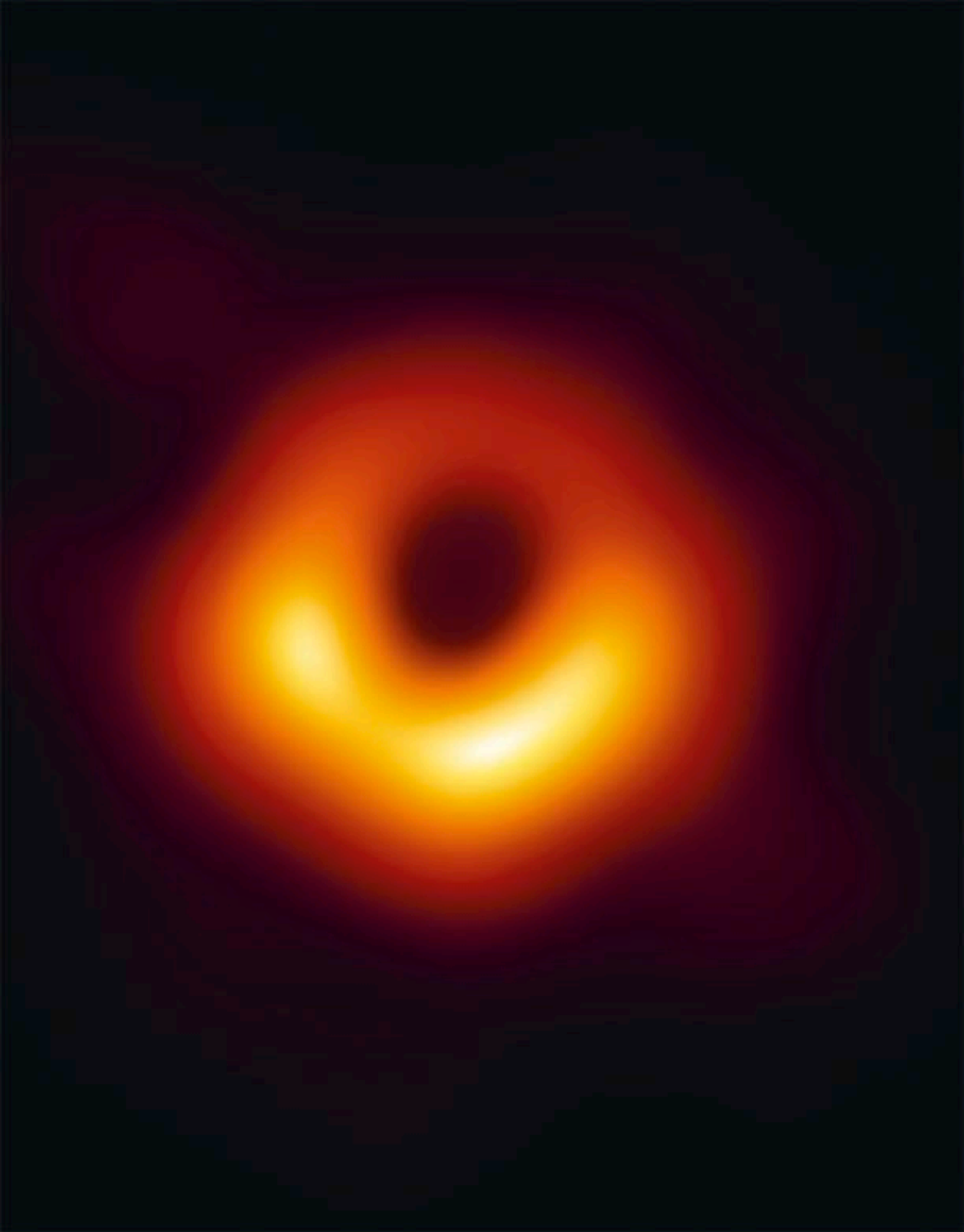
# Black hole

Black holes are among the most mysterious objects in the universe. It's impossible to see them directly, and even the world's smartest scientists do not understand exactly how they work. What we do know is that black holes are an example of nature behaving very strangely indeed.

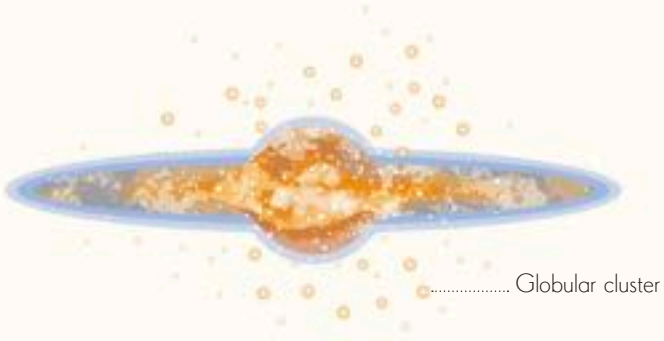
These curious spherical regions warp the space around them dramatically—they have such a strong gravitational pull that even the fastest thing we know of, light itself, is dragged into them. This means they're almost totally black. Some black holes are thought to be born in the explosion that happens when a very massive star dies. There are even bulkier black holes hiding in the hearts of many galaxies too—even our own Milky Way has one!

The galaxy M87 has an enormous black hole at its center, with a mass 6.5 billion times the mass of the sun.

This image is our best-ever view of a black hole's surroundings.



# Globular cluster




Side view of the Milky Way

Where do you think you can see the most breathtaking view of the stars? Looking up at a cloudless desert sky perhaps, or far out at sea on the very blackest of nights? The answer, in fact, is not on Earth at all—it's the view from inside a globular cluster.

These extraordinary objects contain thousands upon thousands of dazzling stars, all packed tightly together in the shape of a ball. Some of the Milky Way's globular clusters could be the leftovers from smaller galaxies that were gobbled up by our galaxy a long time ago. If there are any planets orbiting the stars within these globular clusters, their night skies will surely be awe inspiring, with countless brilliant points of light filling almost every patch of darkness.

The globular cluster Omega Centauri contains at least 1.7 million stars!

Omega Centauri is the largest globular cluster in the Milky Way.

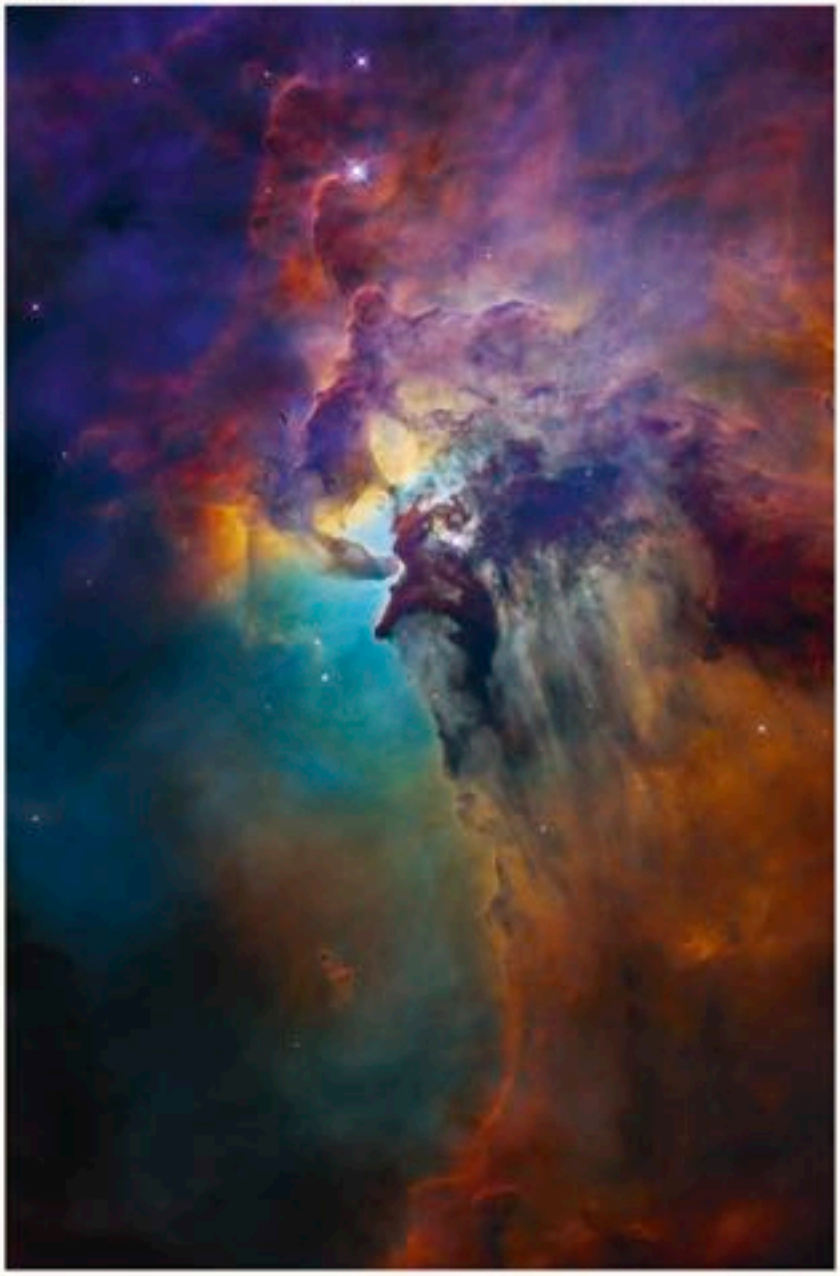
# Nebula

If you were to zoom across the Milky Way in a spaceship, you wouldn't just encounter stars and planets along the way. You'd also pass gigantic clouds of dust and gas that are scattered all throughout the galaxy. Astroners have a name for a cosmic cloud like this: it's called a nebula, and there are several different kinds.

Some, for example, are places where stars are being born, and where gas mingles with blazing new suns to create spectacular glowing shapes. Others are the ghosts of long-dead stars—shining ripples of gas that mark where a star once exploded. With powerful telescopes, astronomers can study these stunning forms even in distant galaxies, far beyond our own.

The Carina Nebula in the southern hemisphere is so bright you can see it without a telescope!

Clockwise from top left; the Witch Head Nebula; the Pipe Nebula; the Lagoon Nebula; the Crab supernova remnant; and the Necklace Nebula.



The striking reddish-pink color of an emission nebula comes mostly from glowing hydrogen gas.

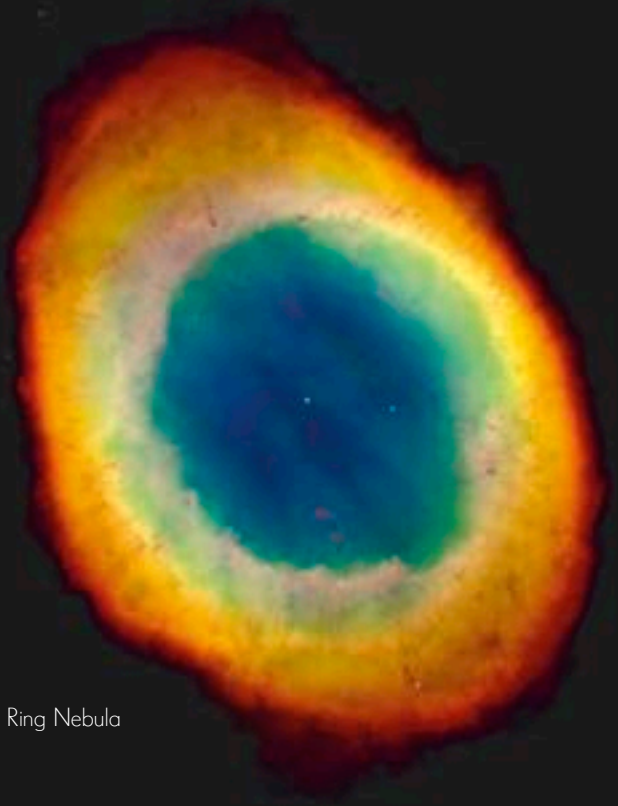
# Emission nebula

Have you noticed that a lot of pictures of the night sky and distant galaxies show splashes of bright pink and red? Each one is a glimmering gas cloud that astronomers call an emission nebula. Some stargazers refer to them as stellar nurseries, because they are regions where new stars are forming inside vast swirls of gas and dust.

An emission nebula gives off its colorful glow because the gases inside are energized by light from hot, young stars that have been born within the cloud. Pick up a good pair of binoculars, and on certain nights you can probably see an emission nebula for yourself!

The Lagoon Nebula sits within the constellation Sagittarius.

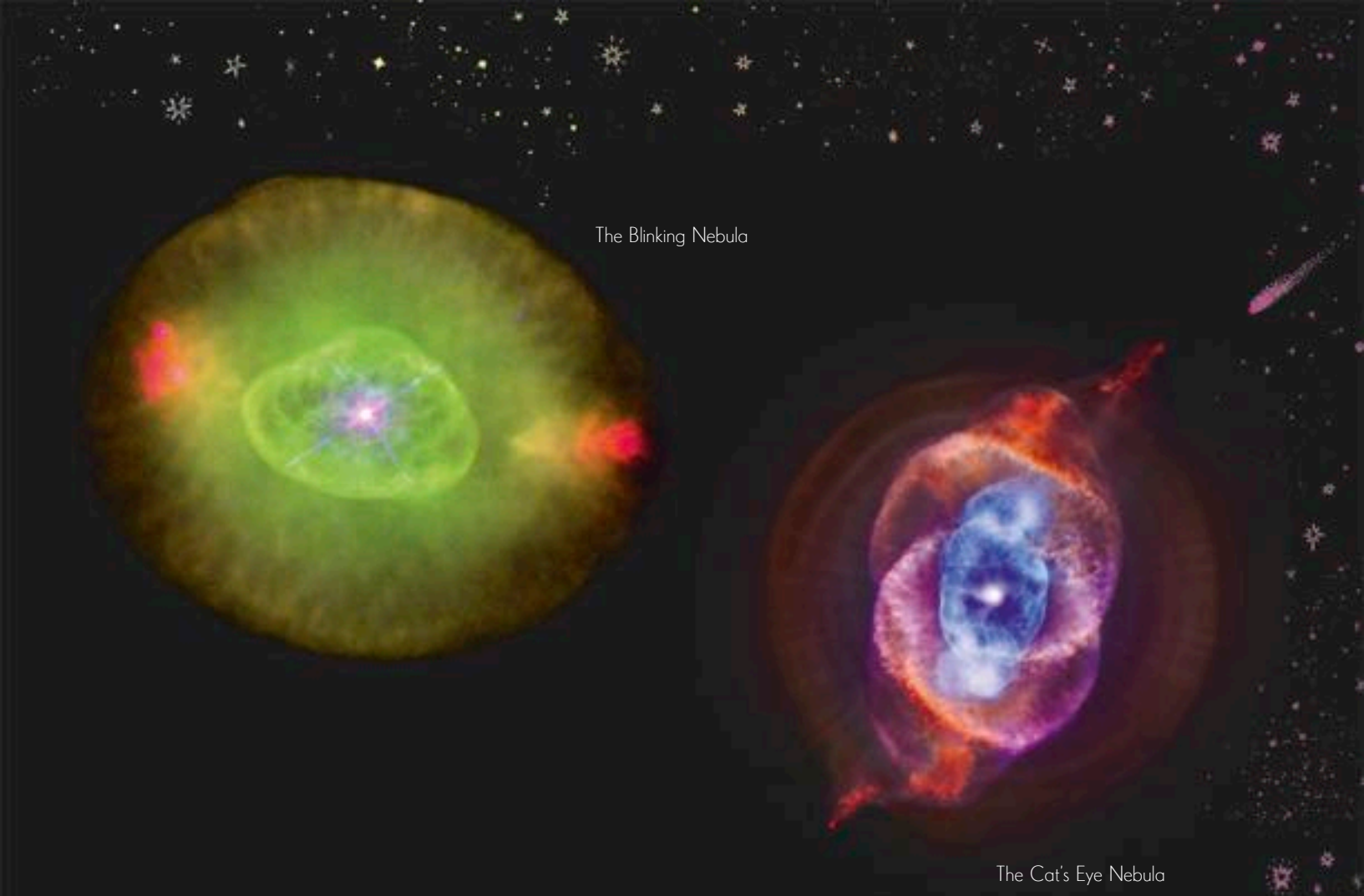
# Planetary nebula



The Ring Nebula

The Southern Owl Nebula

The Ring Nebula is about
6.2 trillion miles (10 trillion km) across.



The Blinking Nebula

The Cat's Eye Nebula

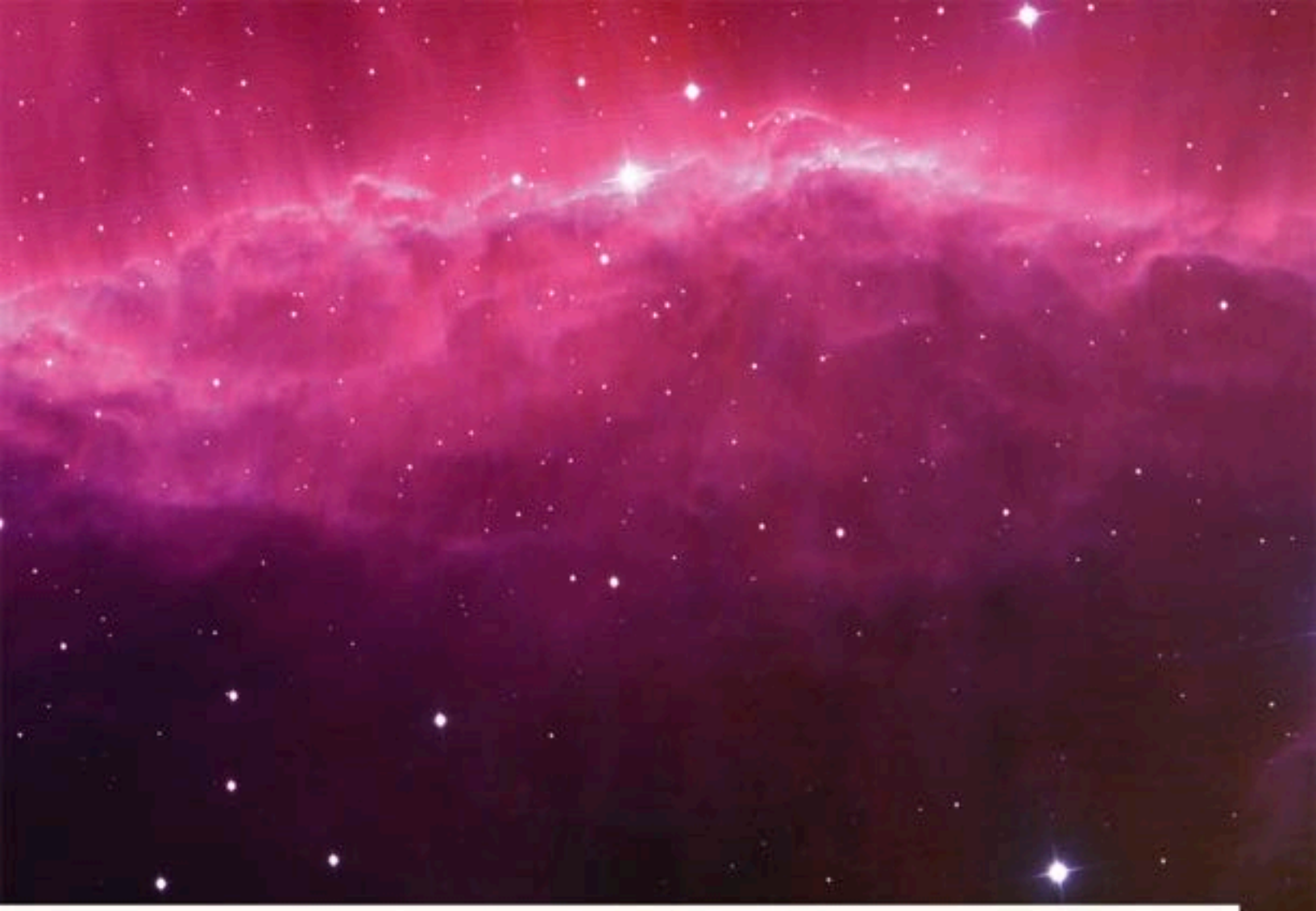
Imagine you were out on a clear night peering at the stars through a telescope eyepiece and you stumbled across a sight like this—what would you say it looked like? To some of the astronomers who first saw these distant celestial objects, the rounded, glowing gas clouds resembled faraway planets, so they became known as planetary nebulae.

In fact, they've got nothing to do with planets at all. A planetary nebula is what bursts into being at the end of some stars' lives. Each nebula you see here was produced when a star, probably quite similar to our sun, grew old and shed its atmosphere. As the star's bulk puffed out into space its searing core was revealed. This core still glows today and it pumps energy into the star's jettisoned atmosphere, making it shine in all kinds of fantastic colors.

# Dark nebula

Dark nebula

The temperature of the dust swirling inside the Horsehead Nebula is about -418˚F (-250˚C).



This nebula is called the Horsehead Nebula—it's easy to see why!

Not all the clouds of dust and gas in our galaxy glow brightly. Many just lurk in the darkness of space, appearing only as silhouettes against brighter backgrounds or dense fields of stars. These cold, so-called dark nebulae can be found throughout outer space, and they include some of the most recognizable astronomical objects, such as the Horsehead Nebula in the constellation Orion and the Coalsack Nebula in the Southern Cross constellation.

By capturing light from these objects that our eyes can't pick up, professional telescopes have shown that some dark nebulae have what may be the beginnings of stars forming within them.

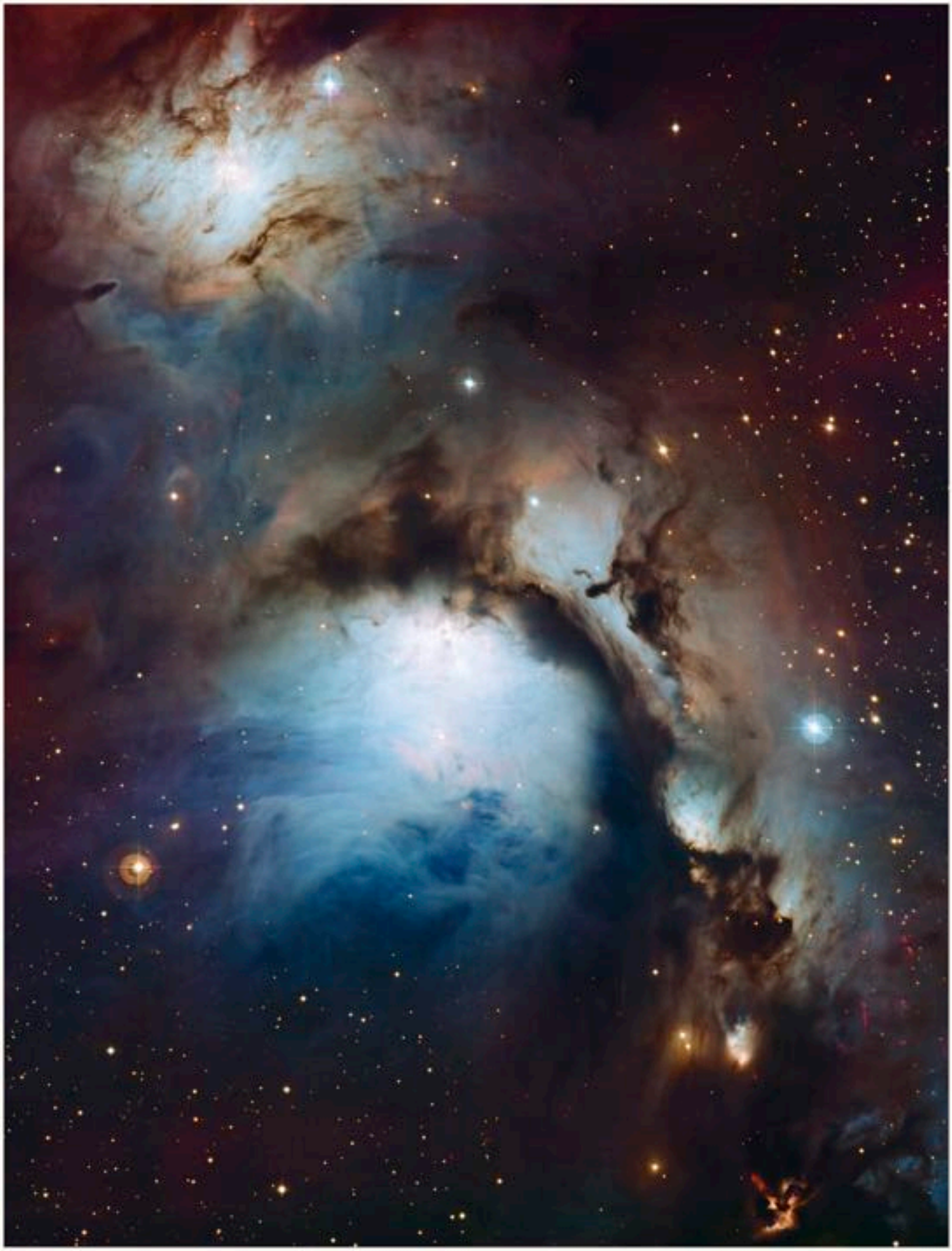
# Reflection nebula

Peer deep into the mystical dust clouds in this faraway corner of our galaxy, and you will see something magical happening. The inner regions of this enormous nebula—known as Messier 78—appear to be shining an otherworldly blue color. There are no wizards at work here, though. In fact, what's happening is that the billowing dust swirls in Messier 78 are scattering the light from stars inside the nebula. The dust scatters the blue in the starlight more than it does the other colors, which gives the nebula its milky blue appearance.

The famous Pleiades star cluster is surrounded by a faint reflection nebula.

Reflection nebula

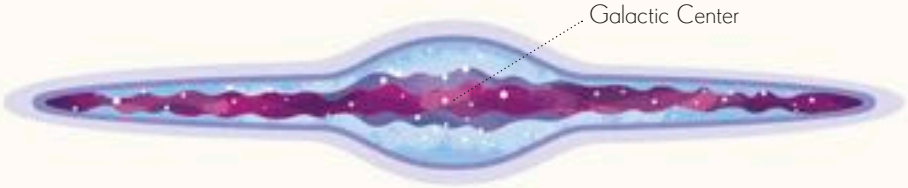
This reflection nebula is called Messier 78. It can be found in the constellation Orion.



# Galactic Center

If you're walking in the country on a misty day, it's sometimes hard to see the beautiful landscape in the distance. Astronomers have a similar problem when they look toward the heart of the Milky Way, known as the Galactic Center. Instead of mist, though, astronomers face huge, obscuring dust clouds floating within our galaxy.

To study the Galactic Center, and to create spectacular pictures of it, astronomers use special telescopes and cameras that can see infrared radiation—a kind of light that is given off by celestial objects. Unlike ordinary light, it can travel through dusty wisps in space, allowing us to get a clear picture of the hidden galactic hub.




The heart of the Milky Way

The way stars are moving around the Galactic Center suggests there's a hefty black hole lurking within.

This infrared image reveals hundreds of thousands of stars in the Galactic Center.

The Pillars of Creation are found in the Eagle Nebula, about 5,870 light-years from Earth.

The Pillars of Creation

# The Pillars of Creation

The billowing clouds of dust and gas where stars form don't last forever. They are gradually sculpted and eventually destroyed by particle-filled winds and the harsh light produced by the stars around them—often the very ones they gave birth to.

The spectacular Pillars of Creation, in the constellation Serpens, give us a glimpse of this extraordinary process in action. The name comes from their location within an enormous stellar nursery called the Eagle Nebula, and the fact that there is a smattering of baby stars cocooned inside them. These dense fingers of gas and dust will ultimately break up and drift out into the galaxy, their glowing forms and swirling shapes never to be seen again.

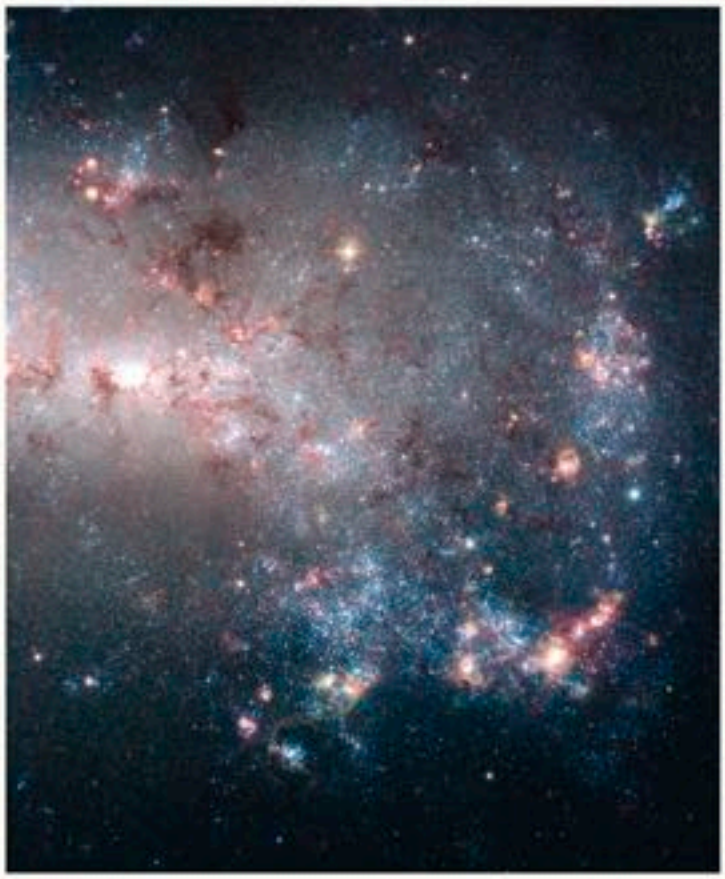
In this image, the green is nitrogen and hydrogen, the red is sulfur, and the blue is oxygen.

This is the visible part of a supernova remnant known as the Cygnus Loop.

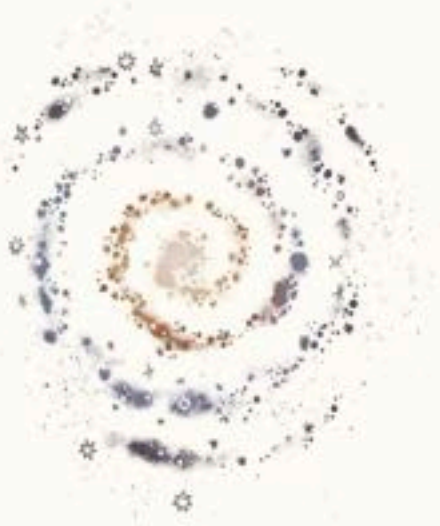
Every human body contains some elements–made by an exploding star–that once floated within a supernova remnant.

# Supernova remnant

When a star dies in a violent supernova explosion, it doesn't simply leave behind a boring patch of empty space. The grand finale of these amazing fireworks displays is the formation of a glowing supernova remnant. These are clouds of rapidly expanding material that surge out into the void where the star once lived. As powerful shock waves race outward, they can also create ghostly tendrils of light that may shine for thousands of years after the dazzling supernova blast has faded.



There are thought to be about 2 trillion galaxies in the observable universe.



# Galaxies

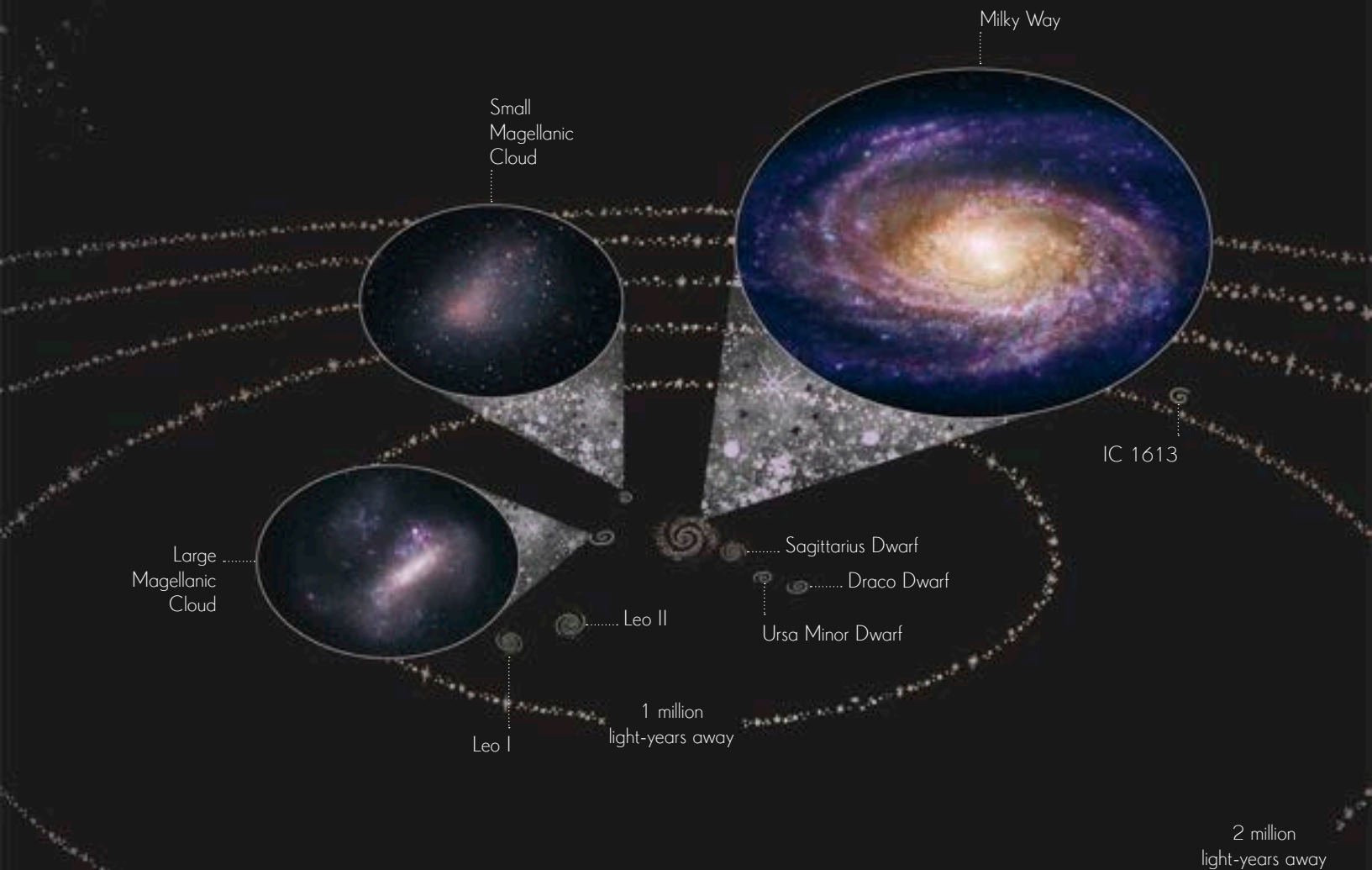
If our eyes were like enormous telescopes, we'd see that—beyond the stars of the Milky Way—the cosmos is full of countless smudges of light. These distant, fuzzy patches are actually enormous collections of stars that astronomers call galaxies.

Like humans, galaxies come in all different shapes and sizes. Our Milky Way, for example, is a spiral galaxy—it has twisting "arms" like a whirlpool. Elliptical galaxies are more rounded, without this beautiful structure, while others, known as irregular galaxies, are little more than a random jumble of stars. One reason astronomers are so interested in learning about faraway galaxies is that they may help us piece together the story of how our galaxy formed. This is because looking deep into space reveals galaxies that lived a long time ago, and these could provide information about the ancestors of the Milky Way.

Clockwise from top; a majestic spiral galaxy; a giant elliptical galaxy; a dwarf irregular galaxy

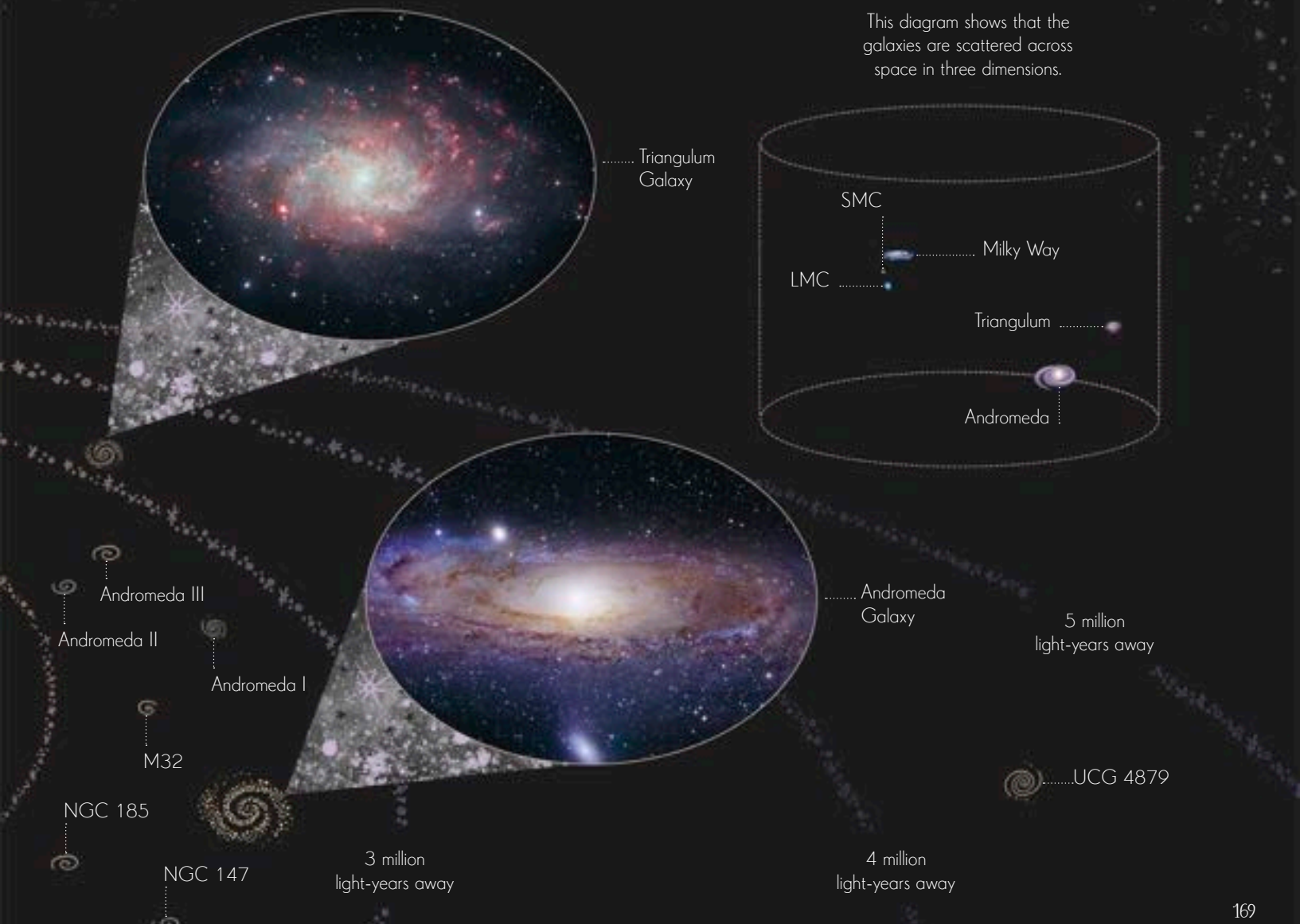
# The Local Group

The farthest member of the Local Group from us is a galaxy called UGC 4879, about 4.4 million light-years away.



You might know your next-door neighbors, or have friends on your street, but did you know that the Milky Way has its own neighbors in space? They're a band of nearby galaxies known as the Local Group.

The larger members of the Local Group include the enormous Andromeda and Triangulum Galaxies and the Magellanic Clouds, which float close to the Milky Way. Astronomers think there are about 75 galaxies in the Local Group.



The Fornax Dwarf is one of the Milky Way's companions.

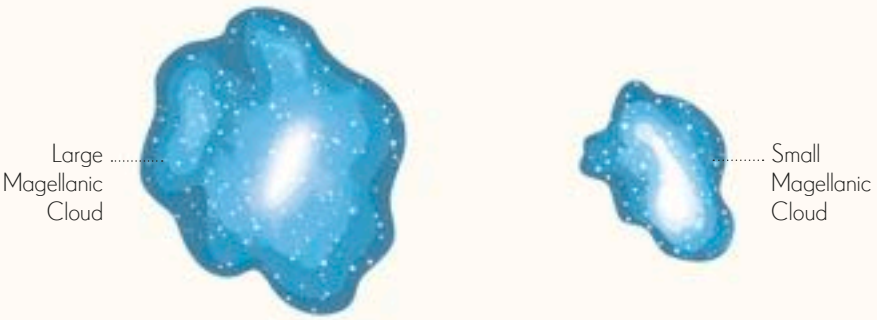
# Dwarf galaxy

Some of the larger galaxies sprinkled across the cosmos are accompanied by smaller galactic friends. These so-called dwarf galaxies might not have the billions of stars of their larger and heftier buddies, but they nonetheless have fascinating stories to tell.

Some dwarf galaxies appear to be responsible for creating huge ribbons of stars that loop around larger galaxies. Scientists call these ribbons stellar streams, and by studying them they may be able to learn more about what happened in our galaxy's wild, violent past. For example, stronomers are examining the stream of stars one nearby dwarf galaxy, the Sagittarius Dwarf, seems to have strewn across space. They think they have figured out what's happening—the Sagittarius Dwarf is slowly merging with the Milky Way.

There are more than 25 dwarf galaxies zooming around our own Milky Way.

The Large Magellanic Cloud is home to many glowing gas clouds, including one that resembles a tarantula!




# The Magellanic Clouds

In a swathe of the glittering night skies of the southern hemisphere, in the constellations of Dorado, Mensa, and nearby Tucana, are two misty patches of light. These glowing objects lie beyond the borders of our Milky Way, and they are known as the Large and Small Magellanic Clouds. They're not really clouds, though. In fact, they're two neighboring galaxies—albeit small ones!

This cosmic pair has almost certainly been observed by the indigenous peoples of the Southern Hemisphere for thousands of years, though their English name comes from the European explorer Ferdinand Magellan, who spotted them while sailing the oceans in the 16th century.

This picture shows part of the Large Magellanic Cloud—it's full of dust, gas, and stars.

The Andromeda Galaxy is a spiral galaxy, like the Milky Way.


The Andromeda Galaxy

# The Andromeda Galaxy

Did you know that just using your eyes you can see more than 2 million light-years out into space? How can you possibly achieve this extraordinary feat? Well, all you need to do is look toward the constellation of Andromeda in the Northern Hemisphere on a clear fall night. Among this collection of stars is a swirl of light known as the Andromeda Galaxy. This beautiful galaxy appears as a faint, glowing patch, shaped a bit like a grain of rice. The Andromeda Galaxy is roughly 2.6 million light-years from us, but it's getting closer. In fact, in about 6 billion years' time it will actually merge with the stars of our own Milky Way!

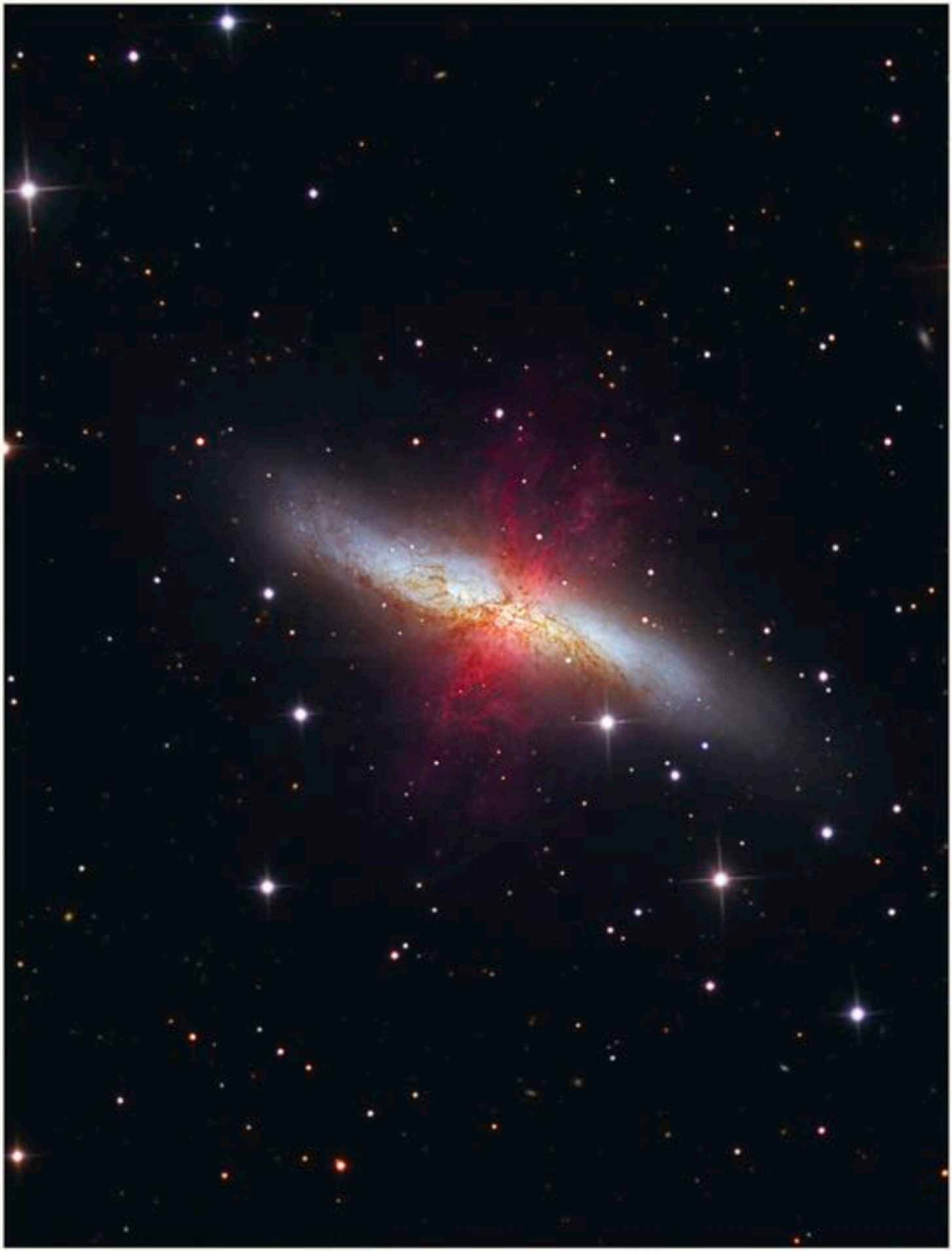
This galaxy is racing in our direction at more than 244,000 miles (393,000 km) per hour!

# Starburst galaxy

Can you see the enormous red wisps flowing from the center of this galaxy, known as Messier 82? Astronomers think they are swirls of gas and dust that have been swept into space by the winds from hefty stars living within the galaxy, as well as the effects of exploding stars. Galaxies that show signs of this activity are often called "starburst" galaxies, and the material shooting from them can be millions of degrees Fahrenheit in places! Precisely how this amazing display unfolds is still a mystery, but the view—even from light-years away—is usually spectacular!

Messier 82 sits near the shoulder of the Great Bear–the constellation Ursa Major.


The burst of red you can see here is glowing hydrogen gas.



# Spiral galaxy

Among the most beautiful of all the kinds of galaxies are the spirals. These exquisite, sparkling whorls usually have a central region of older, more yellow stars and several curving "arms," where stars are forming in droves, flecked with glowing red nebulae.

Astronomers are still trying to figure out exactly how these spiral arms are made. Are they groups of stars moving around the center of the galaxy like flocks of birds? Or are they the result of enormous ripples traveling through the galaxy's body? Perhaps by studying the spiral galaxy we live in—the Milky Way—we will find the answer!

The arms of spiral galaxies usually contain a lot of hot, young, blueish-white stars.

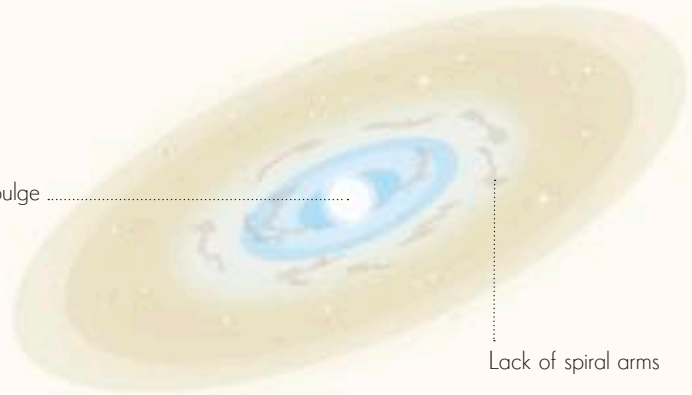
This spiral galaxy is called Messier 74. It is comparable in size to the Milky Way.

# Lenticular galaxy

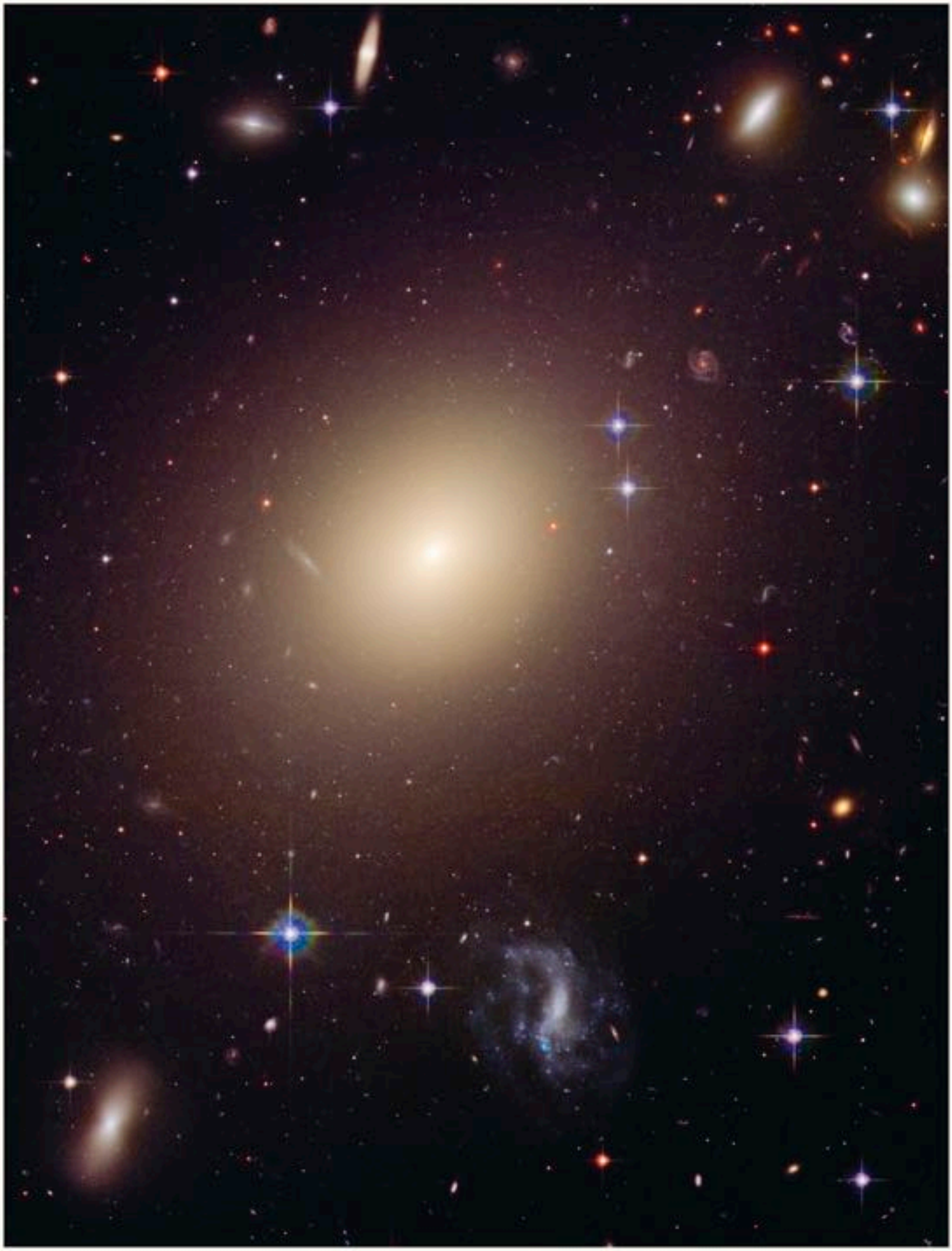
The light reaching us from the Spindle Galaxy left the galaxy 46 million years ago!

Some galaxies that drift through the depths of space aren't quite elliptical, and they don't look exactly like the galactic swirls we call spiral galaxies either. They're somewhere in between. Astronomers refer to these as "lenticular" galaxies, because they have a shape that's a bit like a simple lens—the kind you'd find in a basic magnifying glass.

This beautiful example is known as the Spindle Galaxy, or NGC 5866. It is edge-on to Earth, so we can see its shape perfectly. Scientists are fascinated by lenticular galaxies like this one because they may be what some spiral galaxies become when they stop making stars.

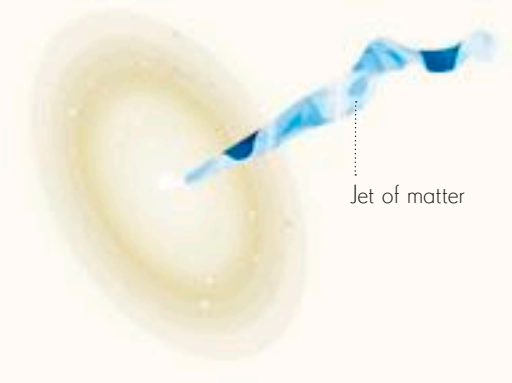



NCG 5866 is about 46 million light-years from Earth.



This elliptical galaxy lies in the center of the Abell S0740 galaxy cluster.

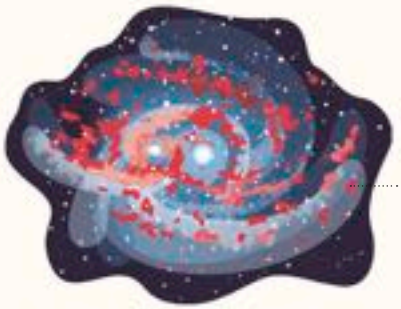
# Elliptical galaxy




There's a jet of matter, about a third of the size of our Milky Way, shooting from the black hole within the elliptical galaxy M87.

If you were a stargazer on a planet inside an elliptical galaxy, you'd probably get a bit bored with your night sky views. Though these rounded galaxies are often composed of billions of stars, they don't have the magnificent spiral shape of galaxies like the Milky Way. For the most part they also lack the glowing, star-forming gas clouds and dark, dusty nebulae seen in other kinds of galaxy. That doesn't make them any less interesting, though! Some of the largest elliptical galaxies seem to have grown huge by gobbling up other, smaller galaxies. Many of these vast balls of stars have supermassive black holes at their hearts. Who knows what lies inside?

These interacting galaxies are nicknamed "The Mice" because of their long tails!



Red gas appears as new stars form.

# Interacting galaxies

With so many galaxies swarming around the cosmos, it's almost inevitable that sometimes they collide and merge, or at least get really close to each other. When this happens, the galaxies begin an extraordinary slow-motion dance as they start to feel the effects of each other's gravity. This process can last many hundreds of millions of years, and we can see examples of these so-called interacting galaxies all across space. As the galaxies spiral close to their partners, their shapes often become distorted—in some cases, they even fling off enormous, sparkling strands of stars as they pirouette together.

Some galaxy collisions show huge clumps of glowing, red gas where stars are forming in the unfolding chaos.

The most distant galaxies in the Quintet are roughly 277 million light-years from Earth.

# Stephan's Quintet

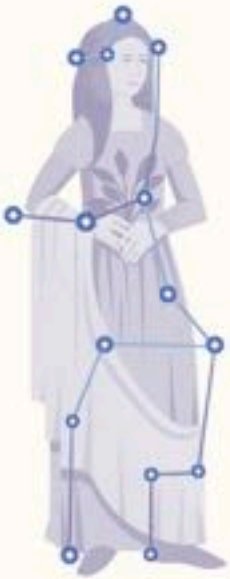
Sometimes, when we see faraway galaxies huddled together, they're not really that close in space—it's just an illusion created by the angle at which we're viewing them. Like distant mountain peaks on the horizon, they look as if they're bunched up and all the same distance away, but in fact they're spread far apart. That's the case for this galactic gathering, known as Stephan's Quintet. Four of the five galaxies really are twirling together through space in a little swarm. Some have even bumped into each other in the past, causing twisting arcs of stars to spray away from their glowing forms. But the fifth galaxy isn't actually part of the group at all—it's much closer to the Milky Way. Can you guess which is the outsider? That's right, it's the blue swirl in the top-left corner.

Stephan's Quintet was discovered by French astronomer Édouard Stephan in 1876.

# The Local Supercluster

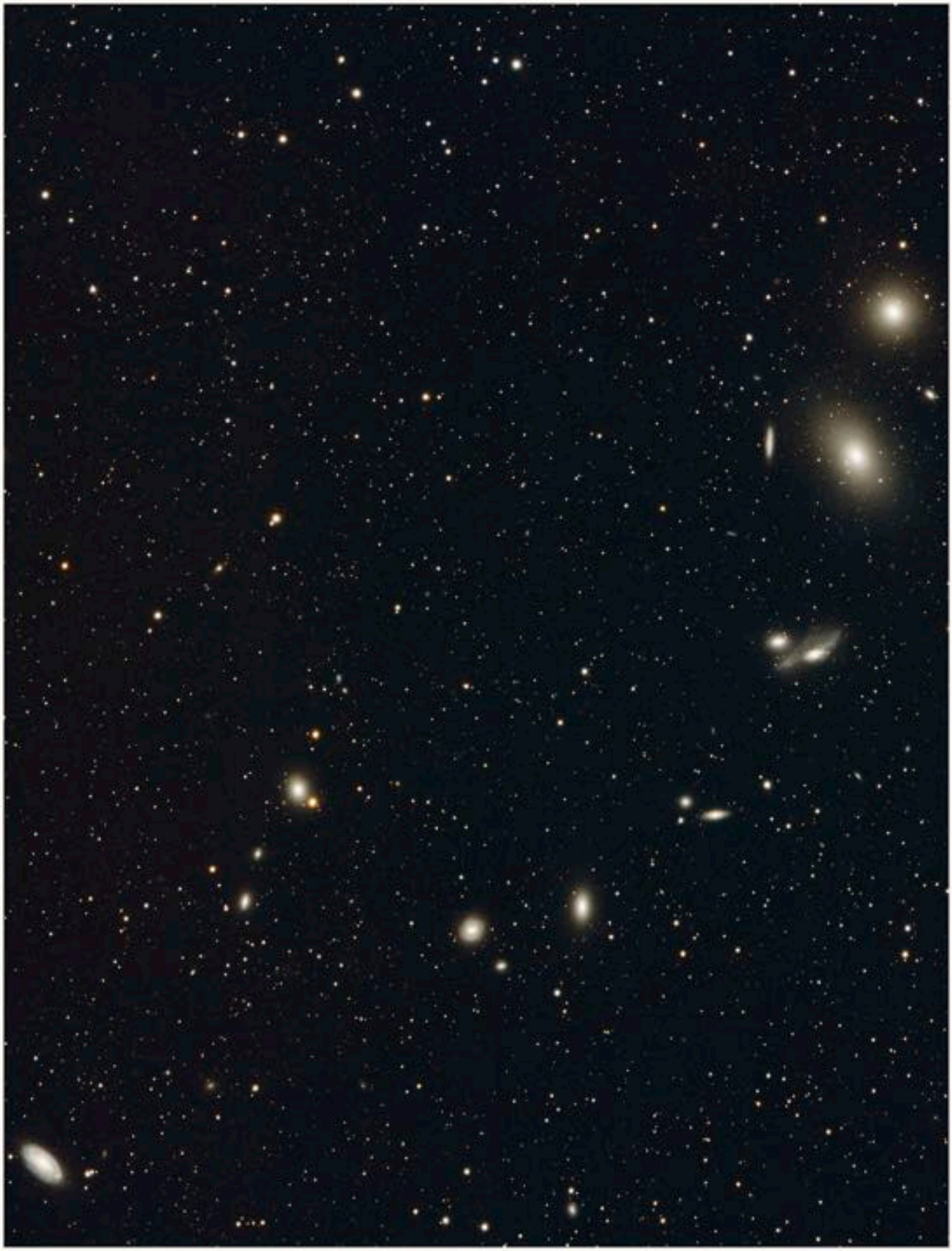
The heart of the Local Supercluster is about 52 million light-years away from Earth.

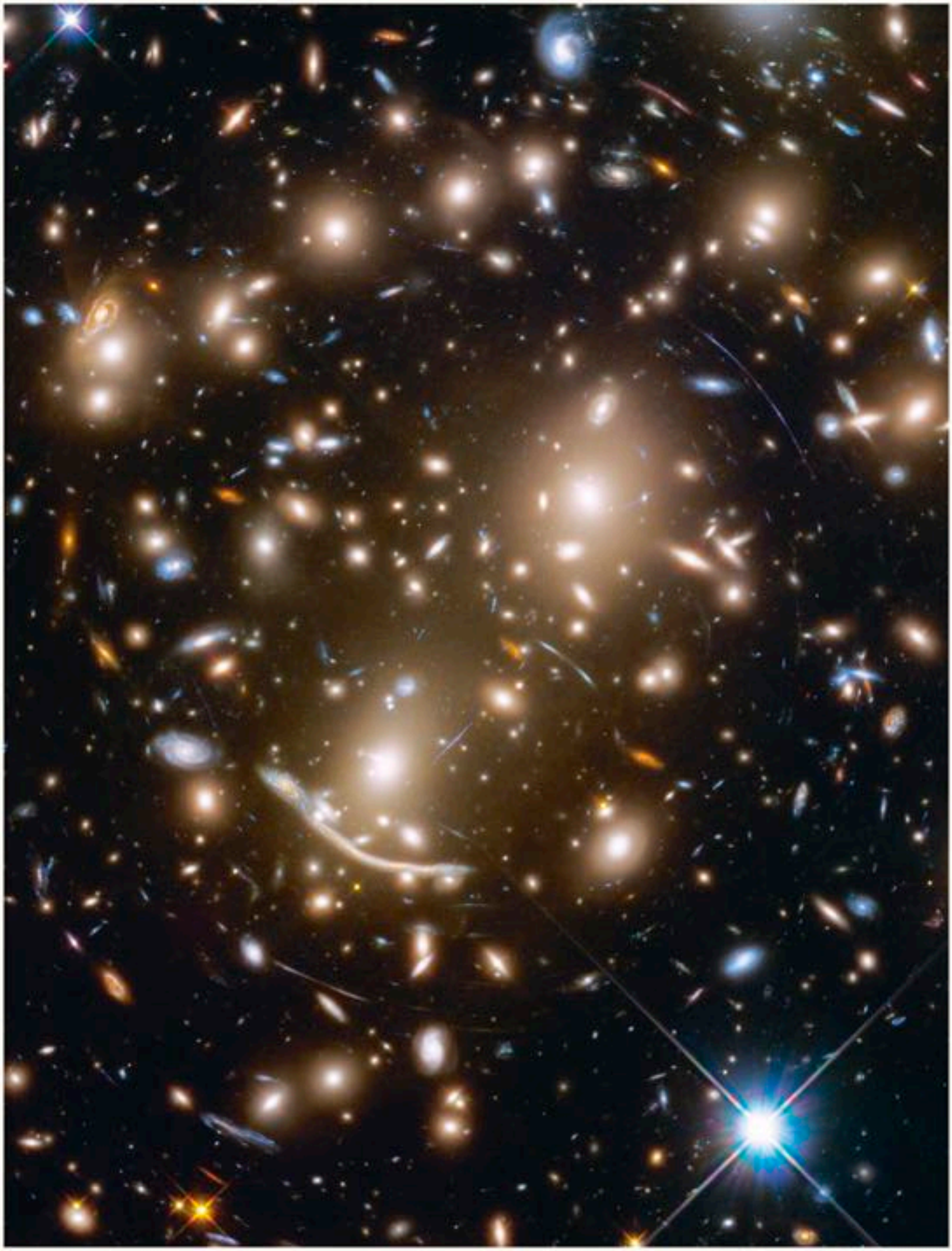
If you think about the Local Group of nearby galaxies as neighbors on our street, the Local Supercluster is the sprawling city that we all live in. This incredible swarm of galaxies, of many different kinds, is thought to be home to thousands of inhabitants—our Milky Way, in the suburbs of this galactic metropolis, is among them. It is sometimes called the Virgo Supercluster because a large part of it sits in the constellation we call Virgo. If you were to hold your outstretched hand up to this patch of the night sky, you'd be covering the locations of tens, if not hundreds, of galaxies in the supercluster!



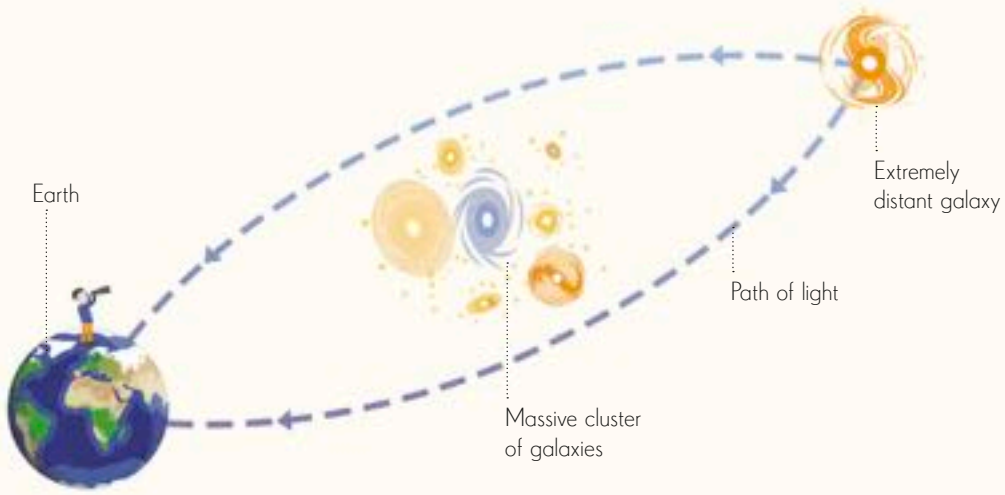
The Virgo constellation

This picture shows Markarian's Chain, a swirl of galaxies that lies in the center of the Local Supercluster.





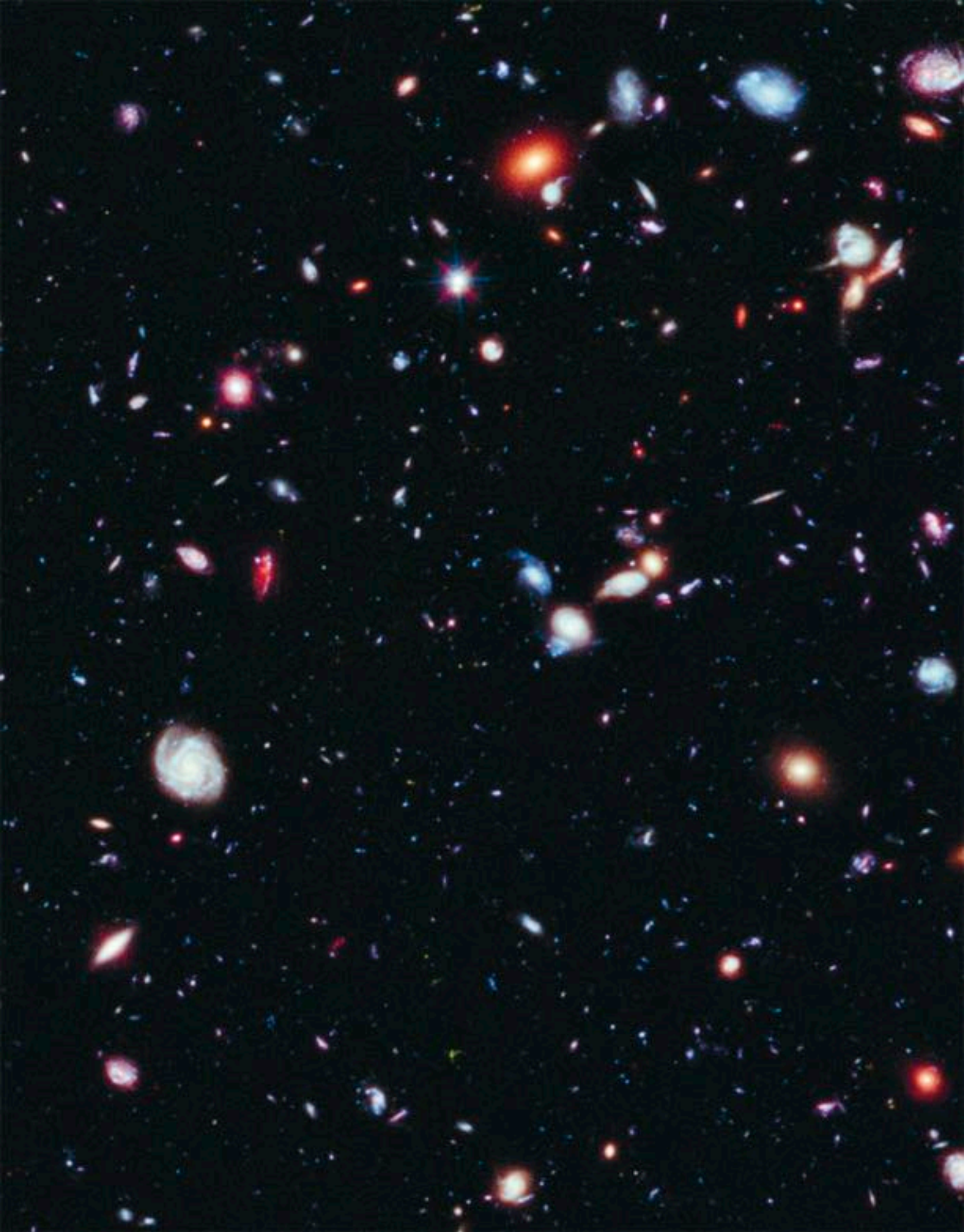
# Gravitational lens




The humongous cluster of galaxies you can see here is so hefty that it is actually distorting space! The path of light traveling toward us from galaxies behind the cluster has been bent by its immense gravity—it is like what happens to light when it passes through an old windowpane, or a telescope lens. This means that our view of distant galaxies is magnified and smeared, making them look like thin arcs of light.

The galaxy cluster in this gravitational lens weighs around 380 trillion times the mass of the sun!

Can you see the thin arcs of light made by this gravitational lens?

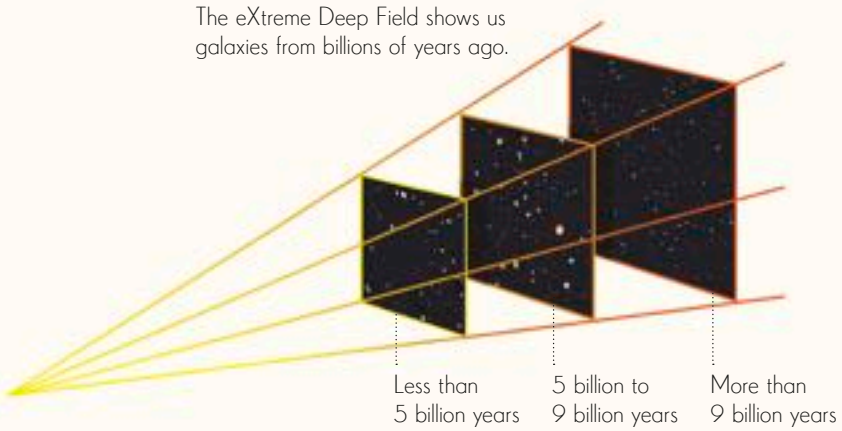


This is the deepest image of the universe ever created!

# Gazing into the past

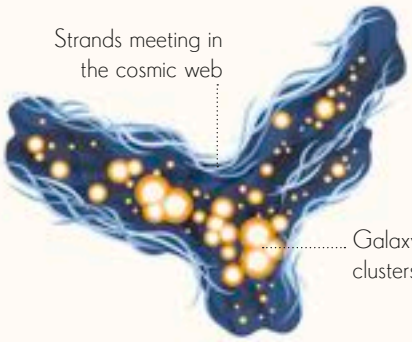
Almost every spot of light you can see in this picture is a faraway galaxy. This incredible panorama, known as the eXtreme Deep Field, was captured by the Hubble Space Telescope, a NASA telescope that orbits Earth. It is one of humanity's furthest glimpses into the distant cosmos, and to produce it, Hubble gathered light for more than three weeks. In fact, when you look at this image you're staring roughly 13 billion years into the past—because that's how long light has been traveling toward Hubble's cameras from some of the faintest reddish-orange galaxies in the frame. Future space telescopes will try to see farther than Hubble's masterpiece, in the hope of learning more about how our cosmos was constructed.

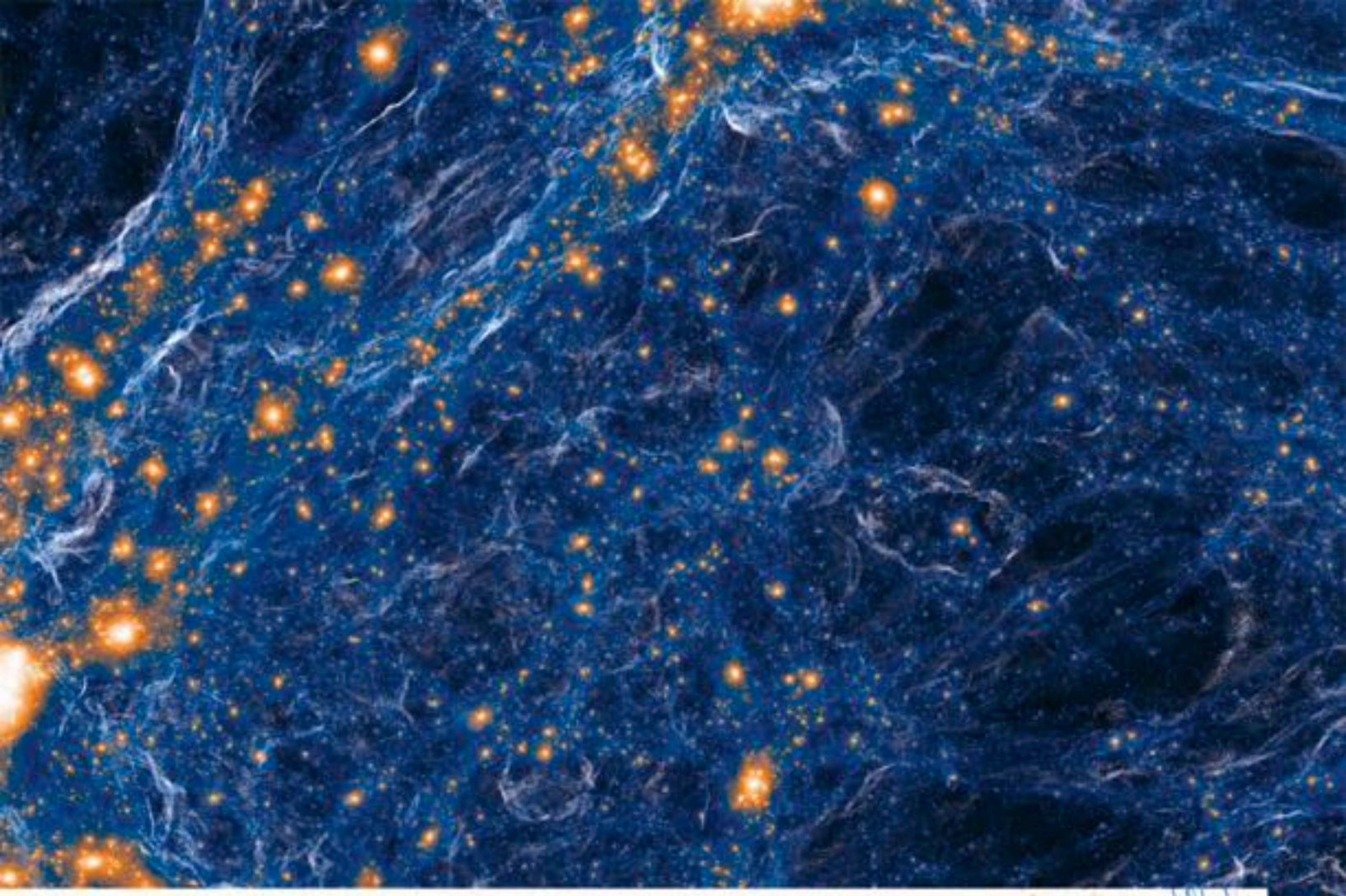
The Hubble Space Telescope has been taking pictures from orbit since 1990!



# The cosmic web

This illustration shows clusters of galaxies linked together by gas filaments.





By carefully charting the distances of numerous faraway galaxies, astronomers have been able to map the shape and structure of enormous sections of the universe. They have found that the cosmos seems to have a texture similar to the inside of a sponge, with huge voids of relatively empty space surrounded by filaments, or threads, made of countless galaxies and other matter.

Scientists today use powerful supercomputers to examine how these strange shapes could have come about—we may be getting close to finding out the secrets of the cosmic web!

Huge clusters of galaxies may form
where strands of the cosmic web meet.

The CMB temperature varies by tiny amounts—red is warmer, blue is cooler.

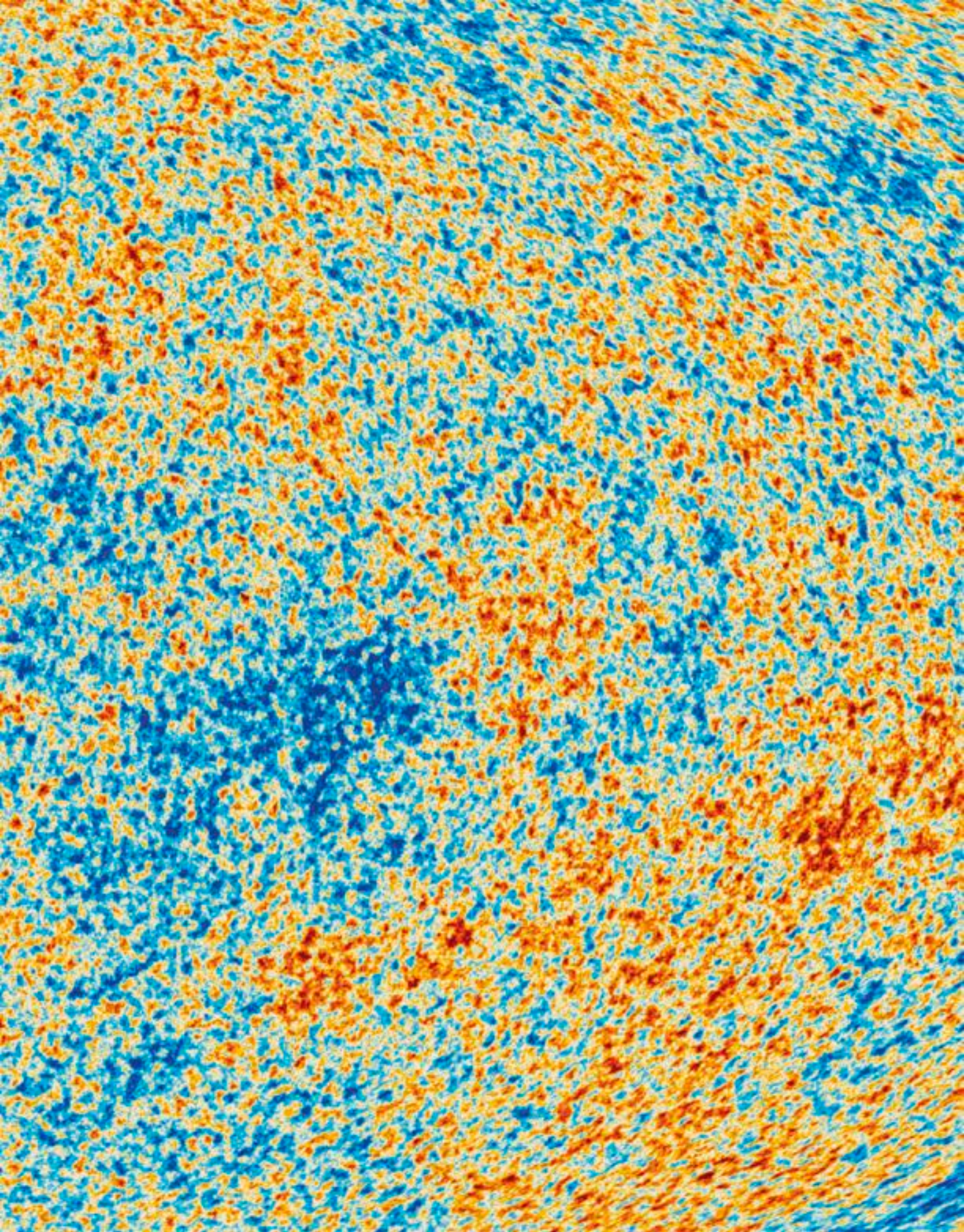
# The cosmic glow

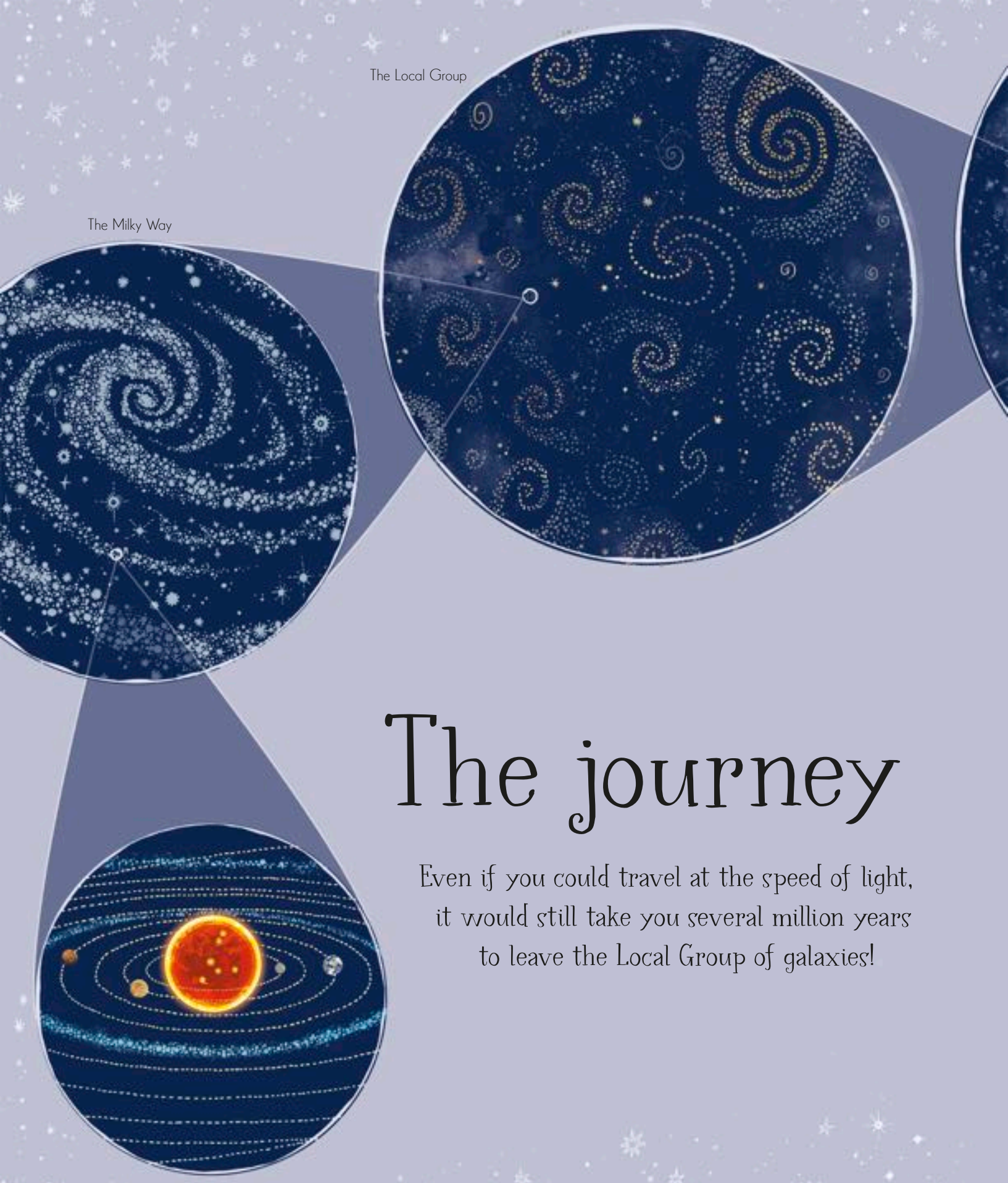
After exploring so much of space—visiting distant worlds and far-off galaxies—we now come to something that appears all over the cosmos. You and I can't see it, but special telescopes used by professional astronomers can. What is it? Well, it's a kind of light. Technically, this light is microwave radiation. It appears in every direction astronomers point their instruments, and is known as the cosmic microwave background (CMB).

Astronomers think the cosmic microwave background is the glow left over from the time just after the birth of the universe—the blazing maelstrom that we know very little about, the Big Bang.

By studying the cosmic microwave background, astronomers estimate that the universe is about 13.75 billion years old.

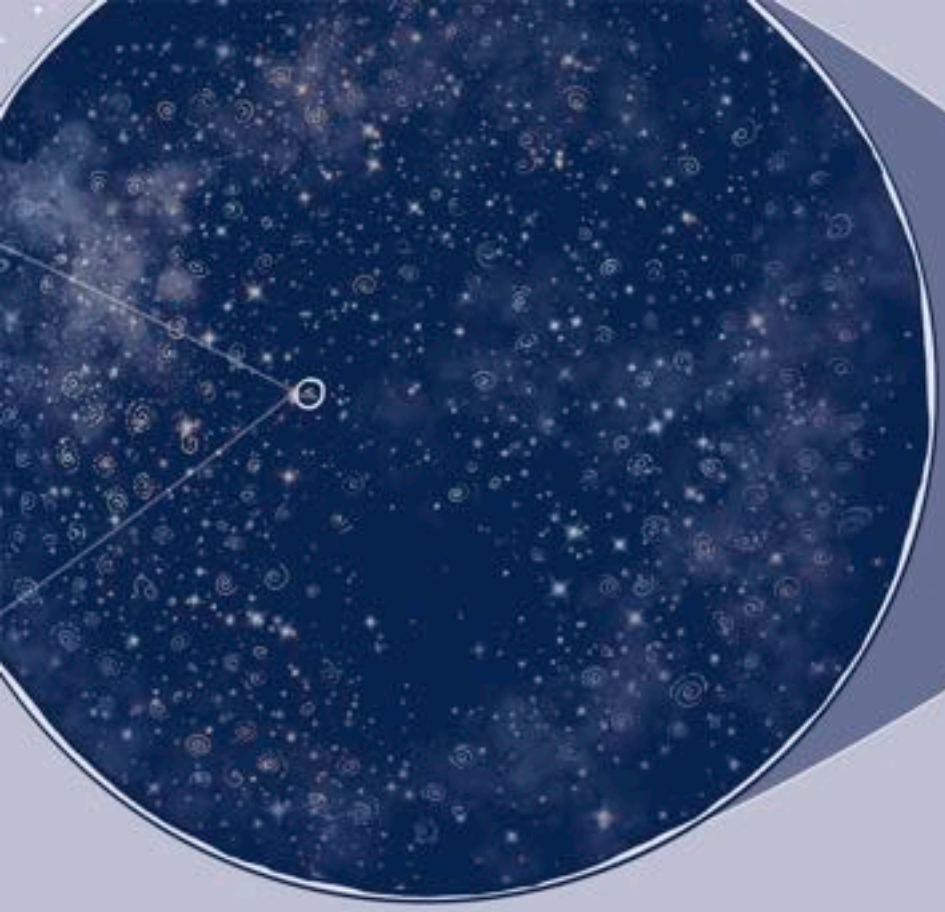
The Big Bang



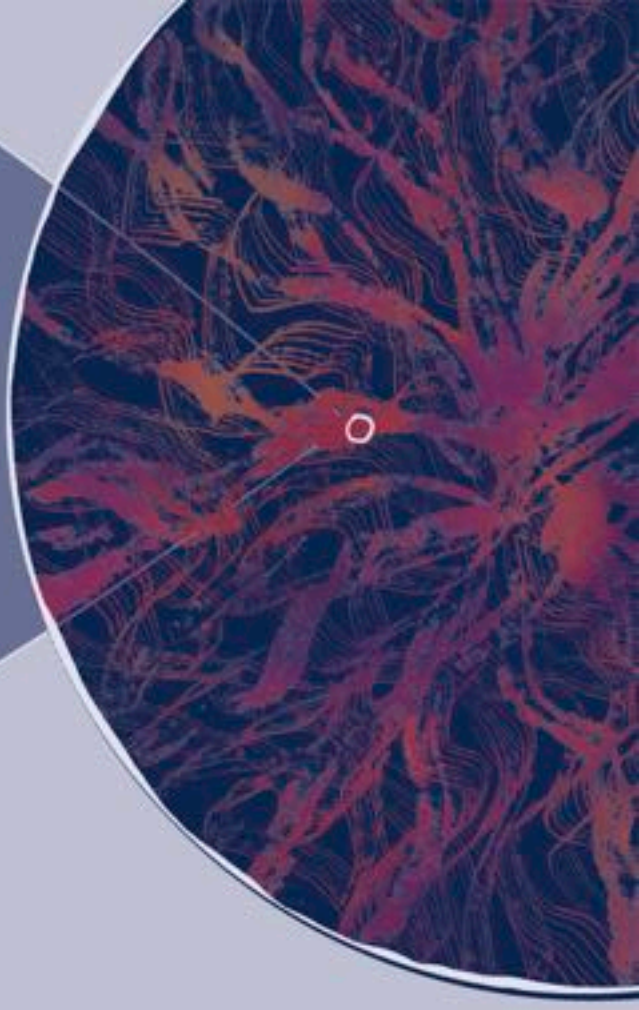



# The journey

Even if you could travel at the speed of light, it would still take you several million years to leave the Local Group of galaxies!



The Local Supercluster

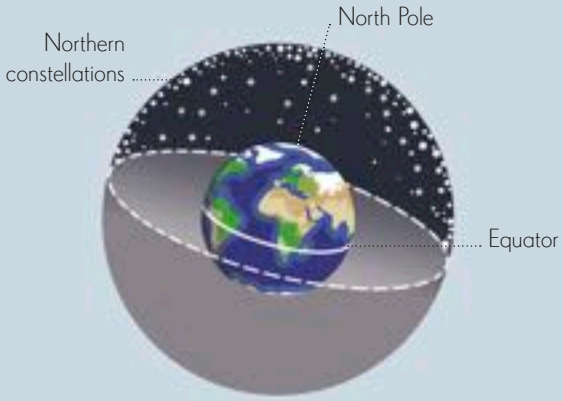


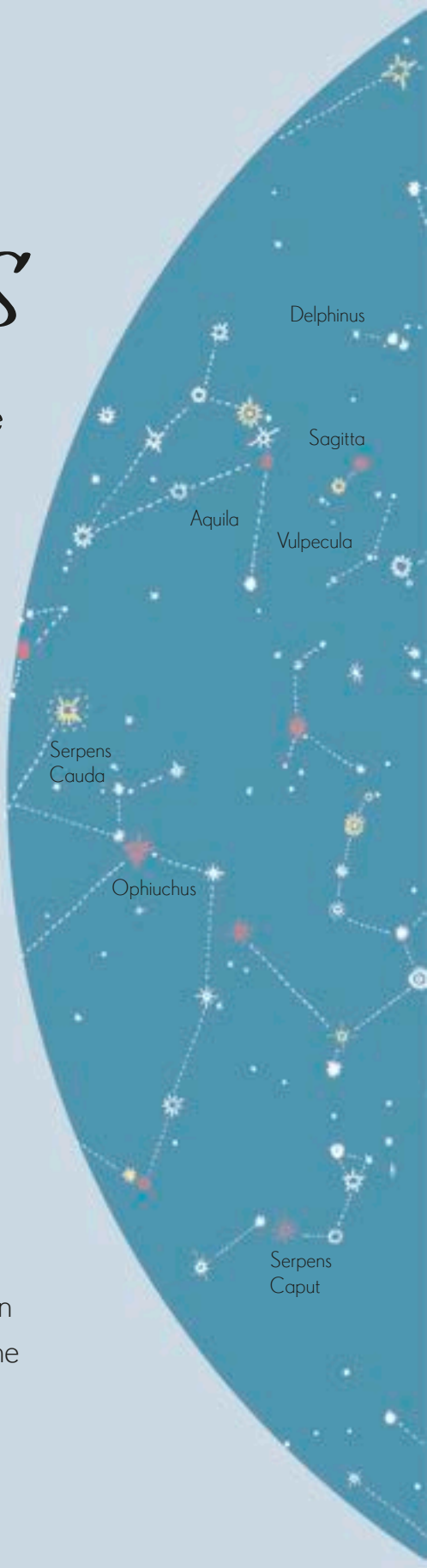
The cosmic web

What an incredible adventure we've been on. We began by staring up at the night sky, marveling at sights that humans have admired for millennia. As we traveled through the solar system, we saw that even close to home there are untold mysteries that science has yet to explore. Leaving our planetary neighborhood, we ventured out into the Milky Way and the wonders scattered within this enormous swirl of stars. Last of all, we explored the secrets of the immense, distant realms of the universe, littered with billions of galaxies of every kind. But that's not really the end. Where will our future exploration take us on this thrilling cosmic journey?

# Northern constellations

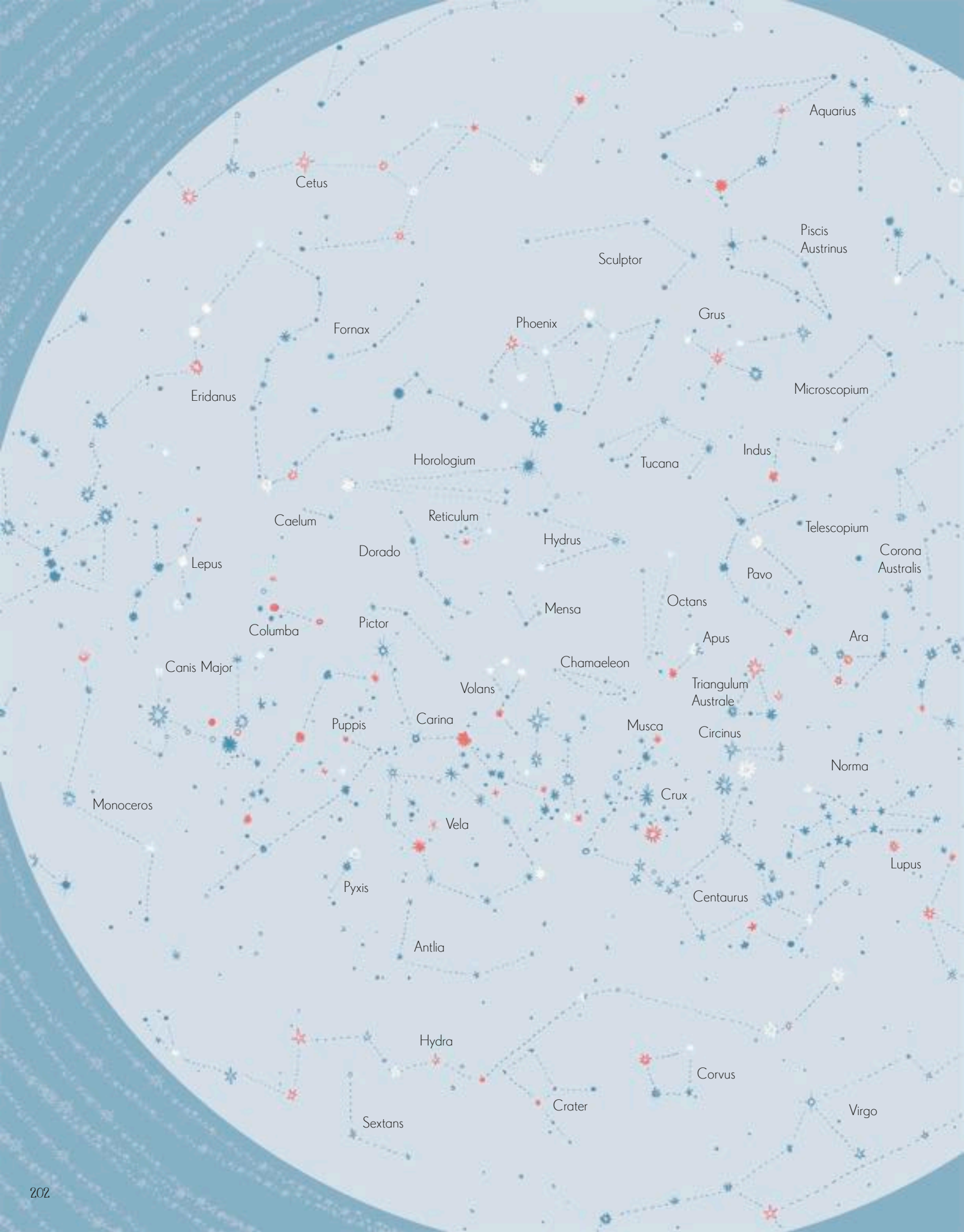
The northern night sky rotates around a point close to the star Polaris in the constellation Ursa Minor.



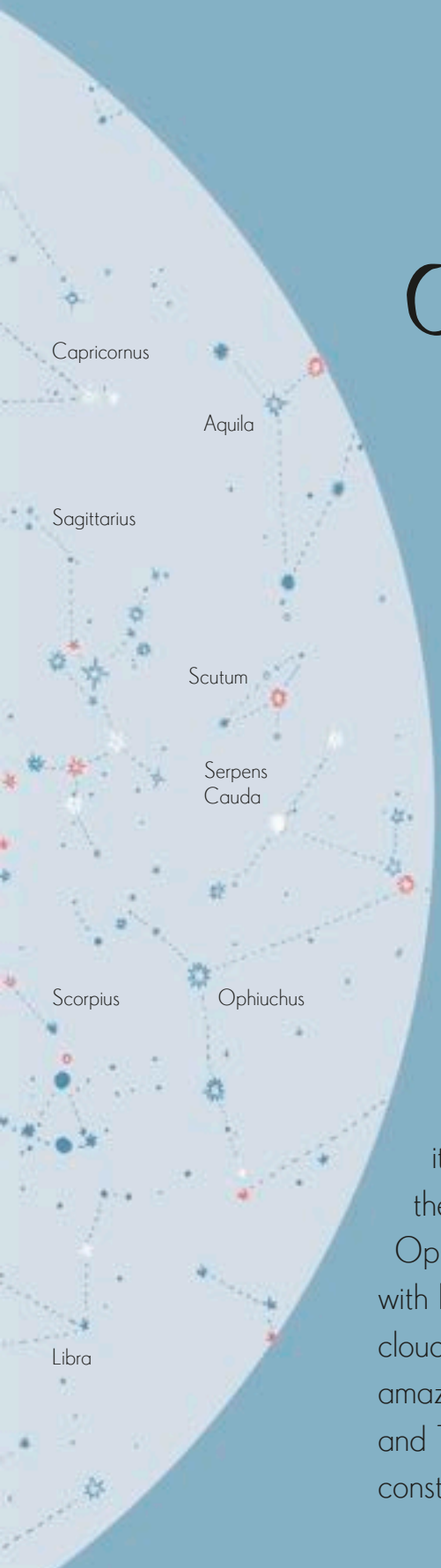




The night skies of the Northern Hemisphere are home to an incredible variety of glittering star fields that change with the seasons. In winter, the constellations Gemini, Taurus, and Auriga are sprinkled with beautiful star clusters that you can marvel at with binoculars. Summer brings with it the possibility of catching sight of the spectacular central regions of the Milky Way, with the misty swathes of countless stars that pass through Sagittarius, Scutum, and Aquila. Spring and fall are when we can look away from our galaxy into the depths of the cosmos, and the distant galaxies that lurk in constellations such as Virgo, Coma Berenices, Triangulum, and Andromeda.

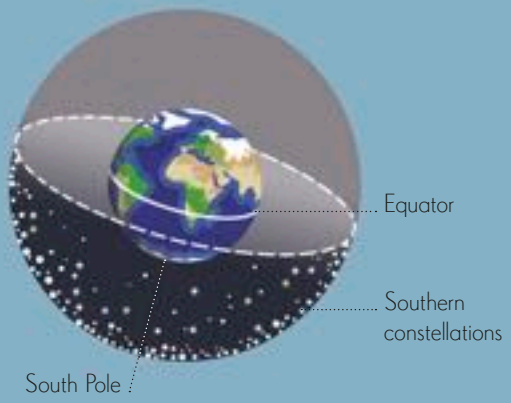

Pisces
Pegasus
Cetus
Equuleus
Andromeda
Aries
Triangulum
Lacerta
Taurus
Cygnus
Cassiopeia
Perseus
Cepheus
Orion
Camelopardalis
Lyra
Auriga
Ursa
Major
Hercules
Draco
Lynx
Gemini
Corona
Borealis
Canis Minor
Leo Minor
Cancer
Canes Venatici
Boötes
Leo Minor
Coma Berenices
Leo
Virgo


Aquarius
Cetus
Piscis Austrinus
Sculptor
Grus
Phoenix
Fornax
Microscopium
Eridanus
Indus
Horologium
Tucana
Reticulum
Caelum
Telescopium
Hydrus
Dorado
Corona Australis
Lepus
Pavo
Octans
Mensa
Columba
Pictor
Apus
Ara
Canis Major
Chamaeleon
Volans
Triangulum Australe
Puppis
Carina
Musca
Circinus
Norma
Monoceros
Crux
Vela
Lupus
Pyxis
Centaurus
Antlia
Hydra
Corvus
Crater
Virgo
Sextans

# Southern constellations




The Southern Hemisphere constellation Volans represents a flying fish.




The Southern Hemisphere night skies contain some of the most breathtaking celestial sights it's possible to see from Earth. That's because from the Southern Hemisphere it's possible to see the central hub of our galaxy—in particular, the areas toward the constellations Scorpius, Sagittarius, and Ophiuchus—high in the sky. This region is absolutely bursting with bright nebulae, glittering star clusters, and dark, galactic dust clouds. The southern night skies are also where you'll find the amazing Large and Small Magellanic Clouds—in Dorado, Mensa, and Tucana—and the globular cluster Omega Centauri, in the constellation Centaurus.

# Discovering space

Here on Earth, we have been trying to solve the mysteries of the universe for thousands of years. These are some of our greatest achievements!

**1840s**
Lord Rosse observes galaxies with an enormous telescope in Birr, Ireland.

**1846**
The planet Neptune is discovered by Johann Galle and Heinrich d'Arrest.

**1786**
Astronomer Caroline Herschel finds her first comet.

**1888**
Williamina Fleming discovers the Horsehead Nebula.

**1908**
A large asteroid or comet enters Earth's atmosphere and explodes over Siberia.

**1912**
Henrietta Leavitt makes an important discovery that helps astronomers calculate how far away distant galaxies are.

**1925**
Astronomer Cecilia Payne publishes groundbreaking research exploring what stars are made of.

**567 BCE**
Possible first recorded sighting of the northern lights, by Babylonian astronomers.

**Around 400AD**
Hypatia of Alexandria writes about astronomy and mathematics.

**1054**
Chinese astronomers witness a supernova, which produced the Crab Nebula we see today.

**1781**
William Herschel discovers the planet Uranus from Bath, England.

**1610**
Galileo Galilei turns a telescope toward the planet Jupiter and sees its four largest moons.

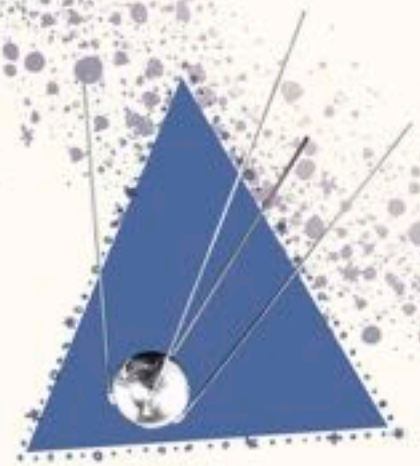
**1609**
Thomas Harriot makes some of the first telescopic studies of the moon.

**1543**
Polish astronomer Nicolaus Copernicus publishes his theory of a sun-centered cosmos.

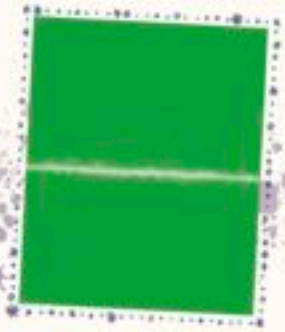
**1929**
Astronomer Edwin Hubble discovers that the universe is constantly expanding.

**1930**
Eugène Delporte draws the 88 constellations recognized today.

**1930**
Clyde Tombaugh discovers Pluto within the Kuiper Belt.



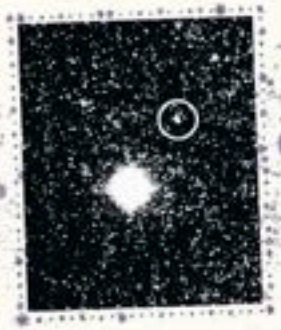
**1957**
The first artificial satellite, Sputnik 1, is launched by the Soviet Union.



**1964**
Scientists discover the cosmic microwave background.

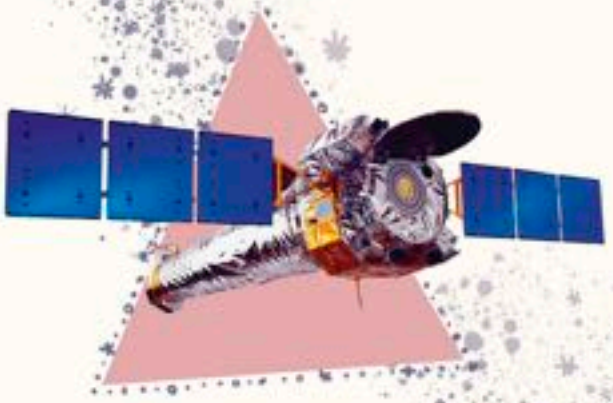
**1967**
Astronomer Jocelyn Bell-Burnell discovers the first pulsar.

**1992 to present**
Astronomers study stars moving around the black hole at the Milky Way's center.

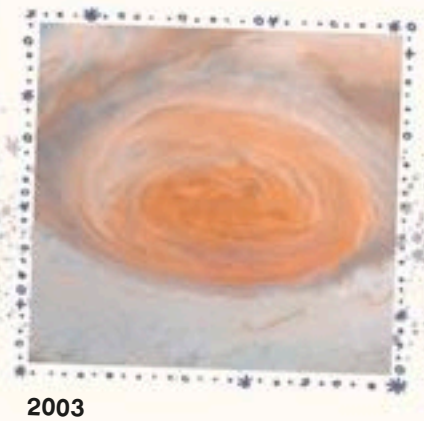


**1992**
The first object, besides Pluto, is discovered in the Kuiper Belt.

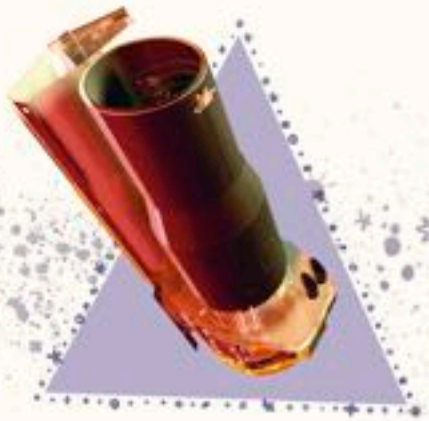
**1990**
The Hubble Space Telescope is launched by the Space Shuttle Discovery.



**1999**
The Chandra X-ray observatory is launched to study objects like black holes and neutron stars.



**2003**
The Galileo probe completes its historic exploration of Jupiter and its moons.

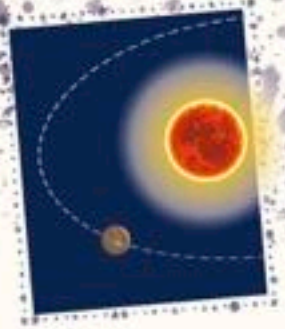


**2003**
The Spitzer Space Telescope is launched to study the infrared light from the cosmos.

**1969**
The astronauts on the Apollo 11 mission become the first humans to step onto the moon.

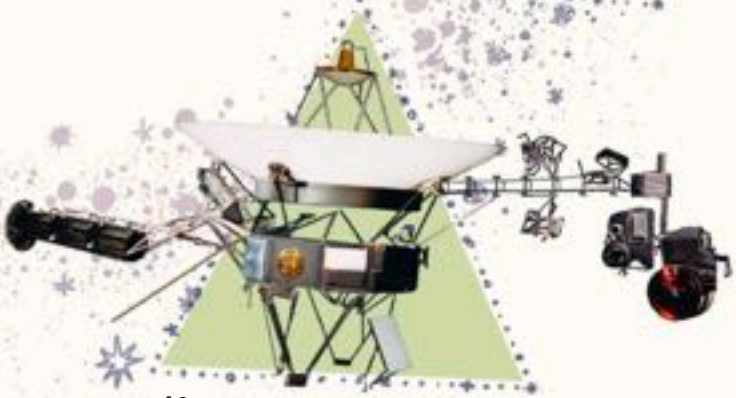
**1970s–1980s**
The Soviet Venera probes land on the surface of Venus.

**Early 1970s**
The first probes successfully land on the surface of Mars.



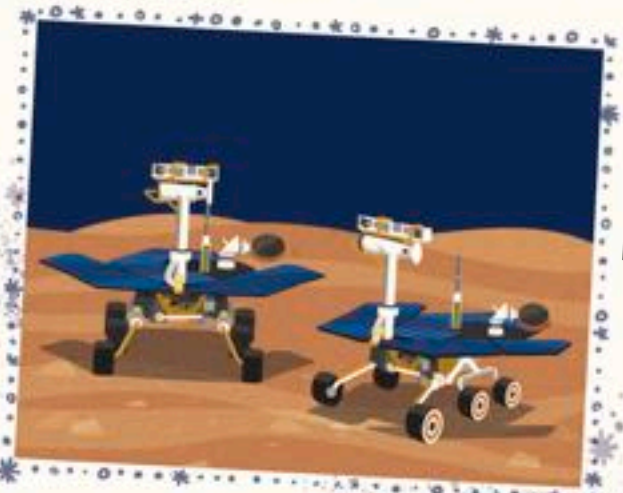
**Late 1980s**
Astronomers make the first discovery of planets orbiting other stars.

**1987**
Supernova 1987A explodes in the nearby galaxy called the Large Magellanic Cloud.



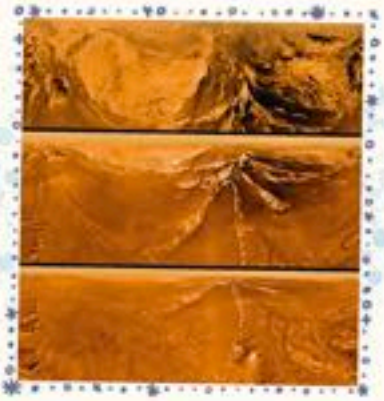
**1977**
The Voyager missions launch to explore the planets of the outer solar system.

**2004**
NASA's Cassini mission enters orbit around the planet Saturn.



**2004**
The twin robotic rovers Spirit and Opportunity land on Mars.

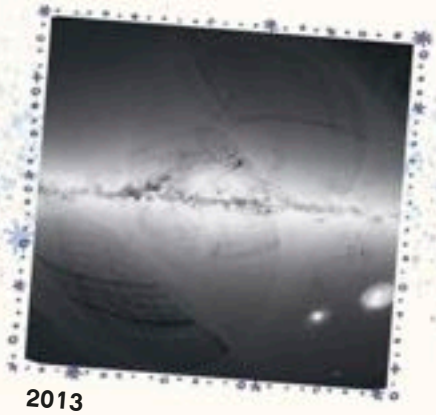
**2005**
The Cassini spacecraft discovers plumes of icy material erupting from Saturn's moon Enceladus.



**2005**
The European Space Agency's Huygens probe parachutes to the surface of Saturn's moon Titan.

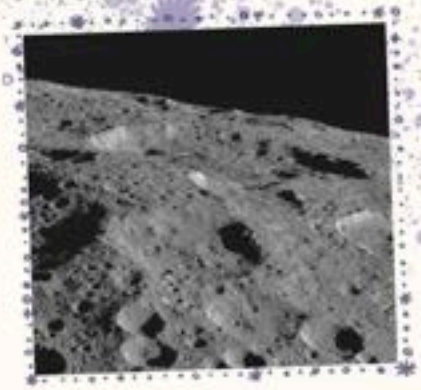
**2006**
The Stardust mission returns samples of comet dust to Earth.

**2014**
The European Space Agency's Rosetta mission reaches Comet Churyumov-Gerasimenko.



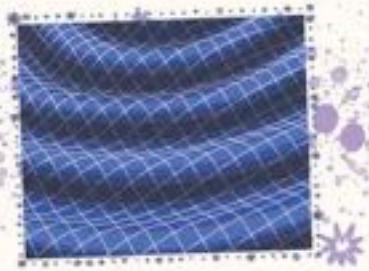
**2013**
Astronomers launch the Gaia spacecraft to map the Milky Way.

**2014**
ESA's Philae probe crash-lands on Comet Churyumov-Gerasimenko.

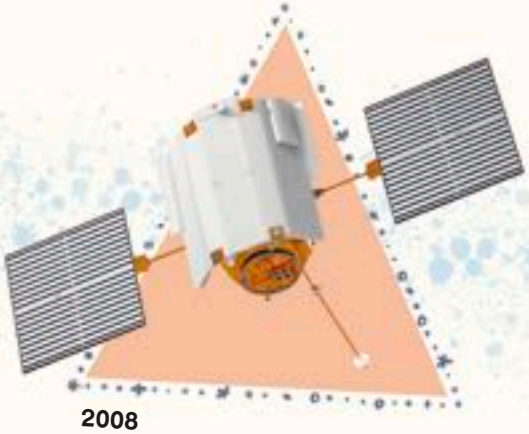


**2015**
The Dawn mission enters orbit around the dwarf planet Ceres.

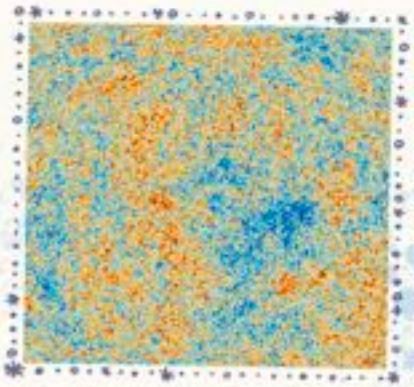
**2015**
NASA's New Horizons spacecraft makes the first flyby of Pluto.



**2015**
Astronomers make the first detection of gravitational waves traveling through space.

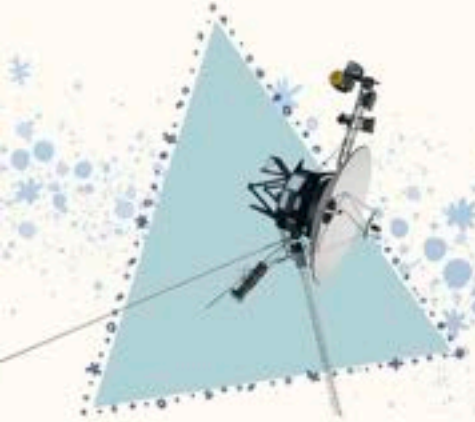


**2008**
The MESSENGER mission arrives at Mercury to study the smallest planet.



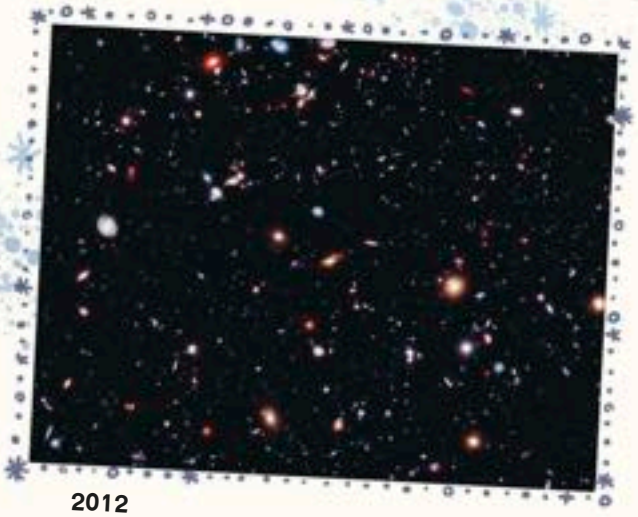
**2009**
The European Planck satellite creates a detailed map of the Cosmic Microwave Background.

**2009**
The Kepler spacecraft is launched to search for planets around other stars.



**2012**
Voyager 1 passes into interstellar space on its way out of the solar system.

**2012**
NASA's rover Curiosity lands on Mars.



**2012**
The Hubble Space Telescope completes the Hubble eXtreme Deep Field image.

**2017**
'Oumuamua, an asteroid from another star system, is spotted passing through our solar system.

**2017**
The Event Horizon Telescope snaps the first picture of the silhouette of a supermassive black hole.

**2019**
The New Horizons spacecraft flies past the Kuiper Belt Object Arrokoth.

# Glossary

**asteroid** a small, lumpy solar-system object usually made of either rock or metals. Many asteroids are thought to be leftover material from the formation of the planets.

**asteroid belt, the** a huge, ring-shaped region of the solar system, located between the planets Mars and Jupiter, that is home to thousands of asteroids. The dwarf planet Ceres also orbits within the asteroid belt.

**astronomy** the study of the night sky and all the celestial objects in it, like stars, planets, and galaxies.

**atmosphere** the layer of gases surrounding the usually solid body of a planet or moon. The Earth's atmosphere is made mostly of nitrogen gas.

**aurora** glowing curtains of light that appear in the atmosphere above the polar regions of Earth. In the Northern Hemisphere they are called the aurora borealis, while in the Southern Hemisphere they are known as the aurora australis.

**Big Bang, the** the name given to the enigmatic event that marked the birth of the universe. Scientists are still trying to understand what happened during the Big Bang. What we do know is that the early universe was incredibly hot and must have quickly expanded in size, eventually becoming the vast cosmos we know today.

**black hole** an incredibly dense, ball-shaped region of space; light cannot travel fast enough to escape the powerful gravitational pull of a black hole, so these mysterious objects are almost completely black.

**comet** a frozen solar-system object composed mostly of ices and dust. Like asteroids, comets come in a variety of lumpy shapes. Most live in the very outer, colder reaches of our planetary neighborhood. If they venture toward the sun they can grow long tails of dust and gas.

**constellation** a pattern of stars in the night sky that usually represents an object, animal, or mythical figure. There are 88 official constellations recognized by the International Astronomical Union today.

**cosmic microwave background** the glow left over from the extremely hot period after the birth of the universe.

**crater** a pit, shaped like a dish, in the surface of a planet, moon, or other solid solar-system object. They are formed when asteroids, comets, and other smaller space rocks crash into a surface, scooping out material in a fiery blast.

**dwarf planet** a kind of small, round, solar-system world that is not a moon or one of the eight main planets. At the moment there are five dwarf planets recognized, including Pluto and Ceres.

**earthshine** light that is scattered off the clouds, oceans, and land of our planet into space, where it can faintly illuminate the night side of the moon's globe.

**elliptical galaxy** a type of galaxy that has a rounded shape similar to a sphere, or sometimes a football. Elliptical galaxies don't have spiral arms like the Milky Way.

**exoplanet** a planet orbiting another star outside of our own solar system. There are likely billions of these worlds in our galaxy!

**Galactic Center** the name for the very heart of our Milky Way galaxy. There is a supermassive black hole at the Galactic Center with stars swirling around it.

**galaxy** a huge gathering of thousands, millions, or sometimes even billions of stars that swirl together through the cosmos.

**galaxy cluster** a collection of multiple galaxies swarming through space in a relatively close group.

**Galilean moon** the four largest moons of the planet Jupiter—Io, Europa, Ganymede, and Callisto—are known as the Galilean moons because they were first seen by the astronomer Galileo Galilei.

**gas giants** the name given to the four large planets of the outer solar system—Jupiter, Saturn, Uranus, and Neptune—which are made largely of gas.

**globular cluster** a densely-packed, ball-shaped collection of many stars orbiting around a galaxy. Many of the Milky Way's globular clusters can be easily seen in the night sky with a small telescope.

**gravity** the force that keeps the planets orbiting the sun, the moon orbiting the Earth, and even vast collections of stars orbiting together as galaxies, among other things. The gravity we feel on Earth is a result of the distortion of space by the enormous mass of our planet. Larger masses—like giant planets, stars, and black holes—curve space more strongly, producing stronger gravitational pulls.

**Hubble Space Telescope** a large telescope, with a 8-foot (2.4-meter) wide mirror, orbiting around Earth. It has helped us to see more of the universe, showing us pictures of glittering star clusters and distant galaxies in extraordinary detail.

**hydrogen** a chemical element that is found all over the cosmos. Most stars are mainly made of hydrogen, and glowing hydrogen is largely responsible for the beautiful red color of many nebulae. Hydrogen is also found in the atmospheres of the gas giants in our solar system.

**interstellar** a word used to describe things between the stars of our galaxy. For example, some of our missions to the outer solar system are now, or will soon become, interstellar travelers as they leave our planetary neighborhood and reach interstellar space.

**Kuiper Belt** a large expanse of the solar system beyond the orbit of the planet Neptune that contains many small, frozen bodies, known as Kuiper Belt Objects. Pluto orbits the sun within the Kuiper Belt region.

**lenticular galaxy** a galaxy, without spiral arms, that has an overall shape similar to that of a simple lens.

**light-year** the distance traveled by a beam of light in one Earth year. Light-years are used as a way to describe the immense distances to and between faraway objects in the universe, such as stars and galaxies.

**lunar sea** the smooth, dark patches on the face of the moon made of a volcanic material called basalt.

**meteor** scientific name for a shooting star. A tiny fleck of space dust that shines briefly as it vaporizes while crashing into Earth's upper atmosphere.

**meteoroid** the name for a small grain of space dust that is floating in space.

**meteorite** a space rock, or a fragment of a space rock, that has made it through Earth's atmosphere to land on the surface of our planet.

**Milky Way** the name of our home galaxy. We see the Milky Way from the inside, since our sun is one of the 200-400 billion stars that live in this enormous, sparkling swirl.

**moon, the** the large, rocky ball that travels with Earth around the sun. The moon orbits our planet at a distance of roughly 239,000 miles (384,000 km).

**moon** the name given to the natural objects—big and small—that orbit around the various worlds, and other objects, in our solar system and beyond.

**nebula** a cloud of gas and dust floating in space.

**neutron star** an extremely dense object, made of neutrons, that is sometimes created when a massive star explodes as a supernova.

**Oort Cloud** a huge sphere of icy, cometlike objects that is thought to surround the solar system.

**open cluster** a relatively loosely-packed bunch of stars sitting within the Milky Way. Usually they are young stars that have formed together within a nebula. They drift through space in a group but usually spread out into the galaxy over time. There are many open clusters in the night sky that are visible using just your eyes or a good pair of binoculars.

**orbit** the path of one celestial object around another—like the Earth's path around the sun, a comet's journey through the solar system, or even the route taken by one galaxy whirling around another. The word "orbit" is also used to describe what an astronomical object is doing when it's moving on one of these paths, i.e. a moon orbits a planet.

**phase** the shape made by where light is falling on the globe of a planet or moon. The phases of our own moon change during the month as it orbits the Earth.

**planet** any one of the eight main worlds in our solar system: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. There are planets around other stars too—see "exoplanet."

**protoplanetary disk** a huge, roughly flat, expanse of gas and dust orbiting a young star. Planets can form from these disks.

**protostar** an object forming within a nebula that may one day become a baby star if special reactions—which make it shine brightly—start within its heart.

**rings** grains, clumps, or large chunks of material, sometimes icy, that orbit around an astronomical object—typically a planet.

**satellite** the word "satellite" usually refers to the human-made objects that travel around the Earth or other bodies in the solar system. Sometimes, though, astronomers refer to moons as the natural satellites of the planets.

**solar system** the varied collection of objects—including planets, moons, asteroids, and comets—that orbit the sun.

**space** the name for the vast celestial realm that lies beyond the Earth's upper atmosphere.

**spiral galaxy** a kind of galaxy that has a flat, circular disk composed of whirlpool-like structures, known as spiral arms. The Milky Way and the nearby Andromeda Galaxy are both examples of spiral galaxies.

**star** an enormous ball of plasma (like a superhot gas) that shines because of reactions going on at its heart. These reactions release energy as matter is fused together in the star's core. Eventually, the reactions slow down and stop when the star dies.

**supernova** an extremely powerful explosion created by a dying star.

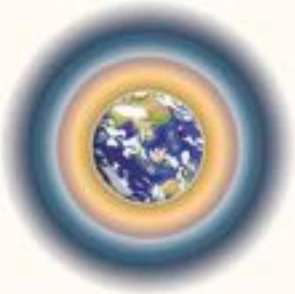
**telescope** a tool used to explore and study the universe. Telescopes work by using mirrors or lenses (or sometimes both) to collect the light from objects in the night sky. Because they can gather more light than our eyes can, telescopes allow astronomers to examine faint targets like faraway galaxies and nebulae. Sometimes this is done by the astronomer looking through the eyepiece of the telescope. These days professional astronomers use special cameras on their telescopes to record images and other pieces of scientific information about a celestial target.

**sun, the** the star at the center of the solar system.

**universe, the** humanity's name for the space that is home to everything we know of, from the most distant galaxies known to our moon right next door.

**volcano** an opening in the surface of a solar-system object where material has erupted out onto the landscape, often forming a mound or large mountain.

# Visual guide



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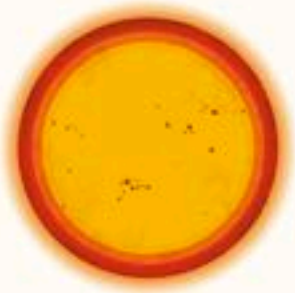







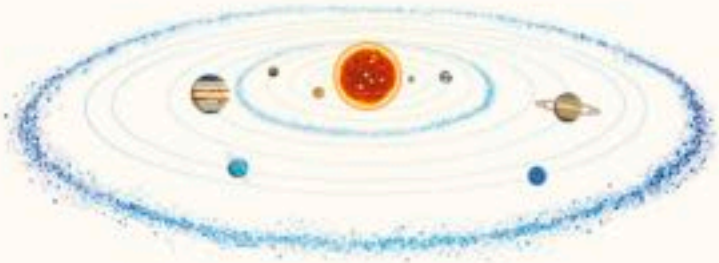





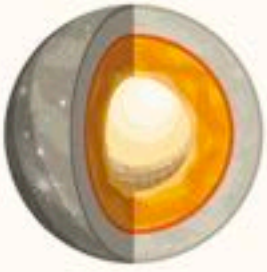































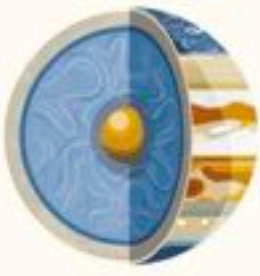



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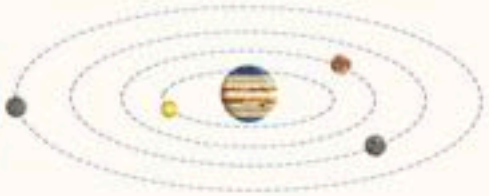

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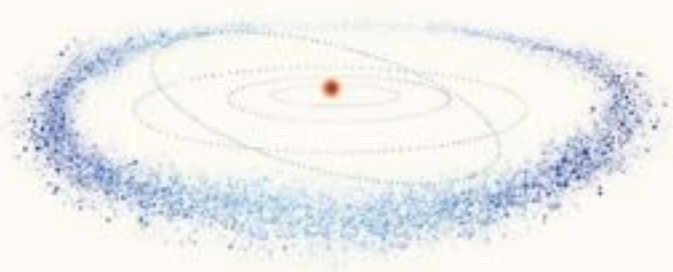

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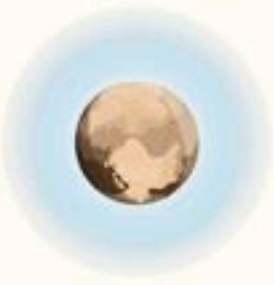

















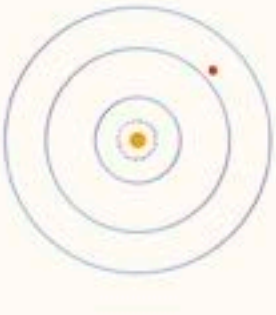











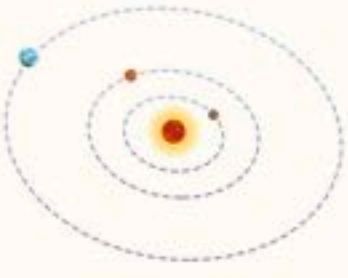









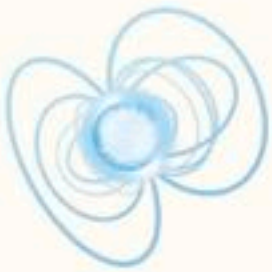





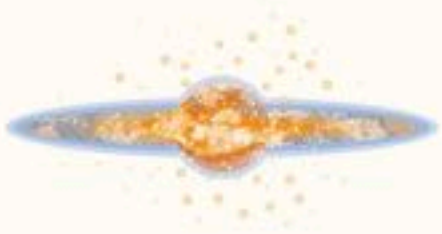























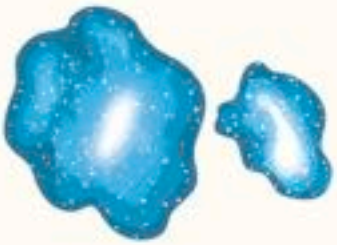















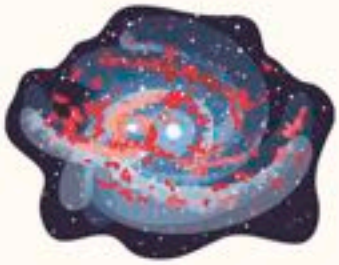









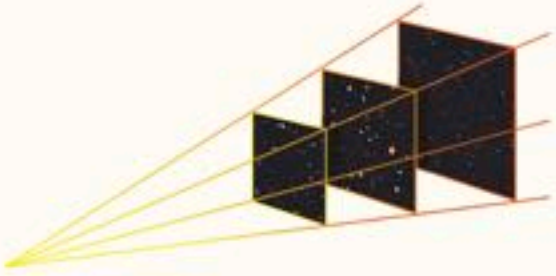



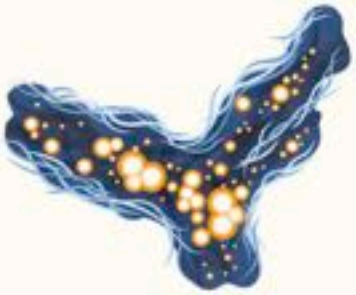



# Beyond this book

I hope that after reading this book you can see what a wondrous universe we live in. It's full of great beauty, breathtaking scale, and captivating puzzles. Some of the questions scientists have about the workings of stars, planets, and even whole galaxies may well be solved in your lifetime. But there will always be more to come.

You'll no doubt have questions of your own as you continue to explore the universe. Don't be afraid to ask them! This is how we learn and find out about the world around us, and beyond. Perhaps one day you'll help solve some of these exciting cosmic mysteries...

Will Gater

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