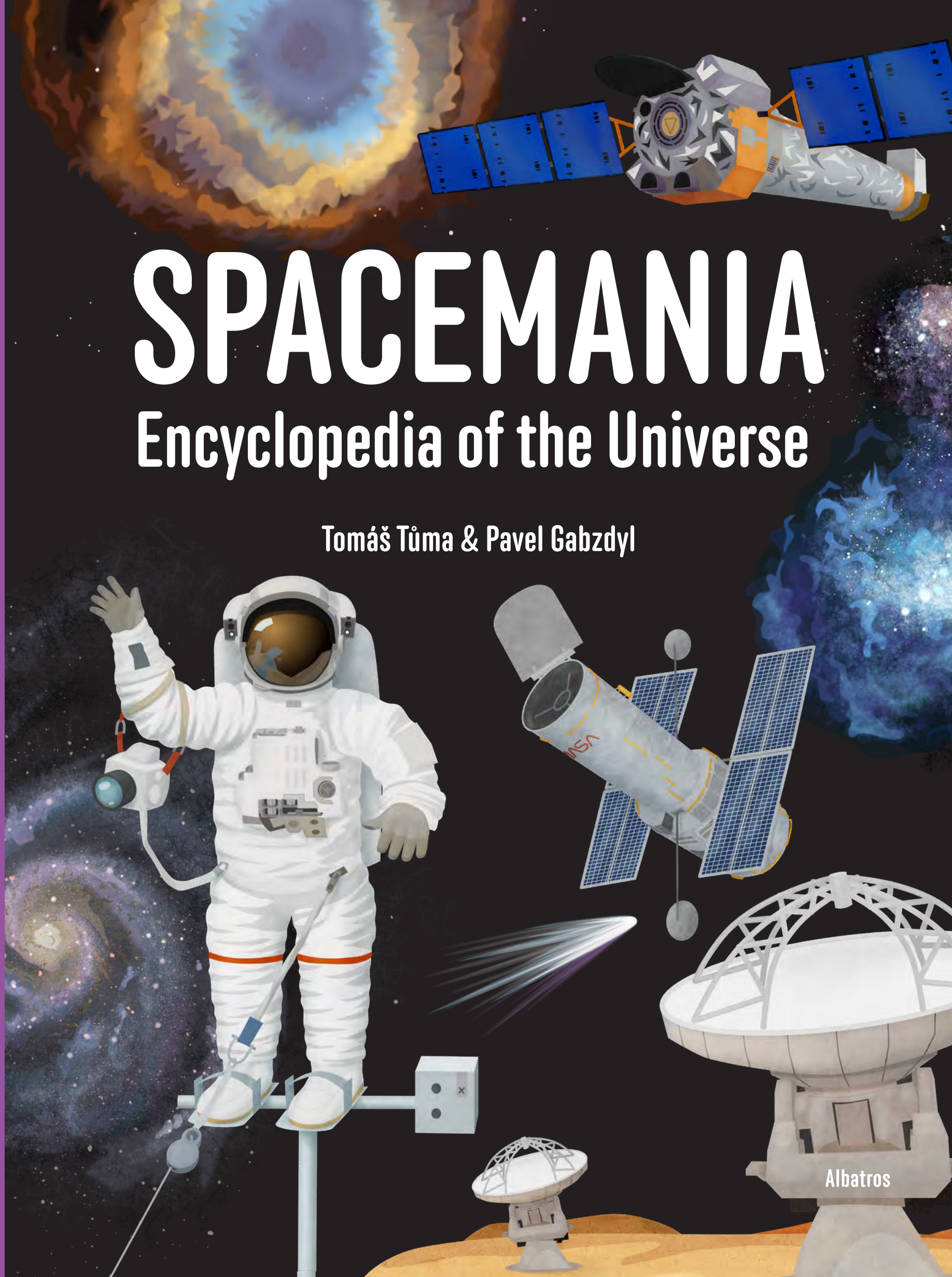
SPACEMANIA

Encyclopedia of the Universe

Tomáš Tůma & Pavel Gabzdyl



Albatros

Tomáš Tůma & Pavel Gabzdyl
SPACEMANIA Encyclopedia of the Universe
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Encyclopedia of the Universe

Written by Pavel Gabzdyl
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Albatros

ORIGINS OF THE UNIVERSE

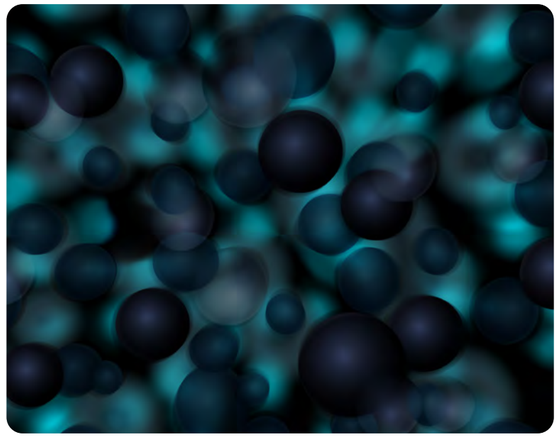
The first second

In the blink of an eye, in a single solitary moment, space and time came to be. Incredible as it is, the entire universe emerged in the first second following the Big Bang.

Modern physics hasn't yet been able to meaningfully describe the period of 10^{-43} seconds following the Big Bang.

From 10^{-43} to 10^{-36} seconds after the Big Bang, gravity became a separate physical force.

The first particles



▲ Big Bang

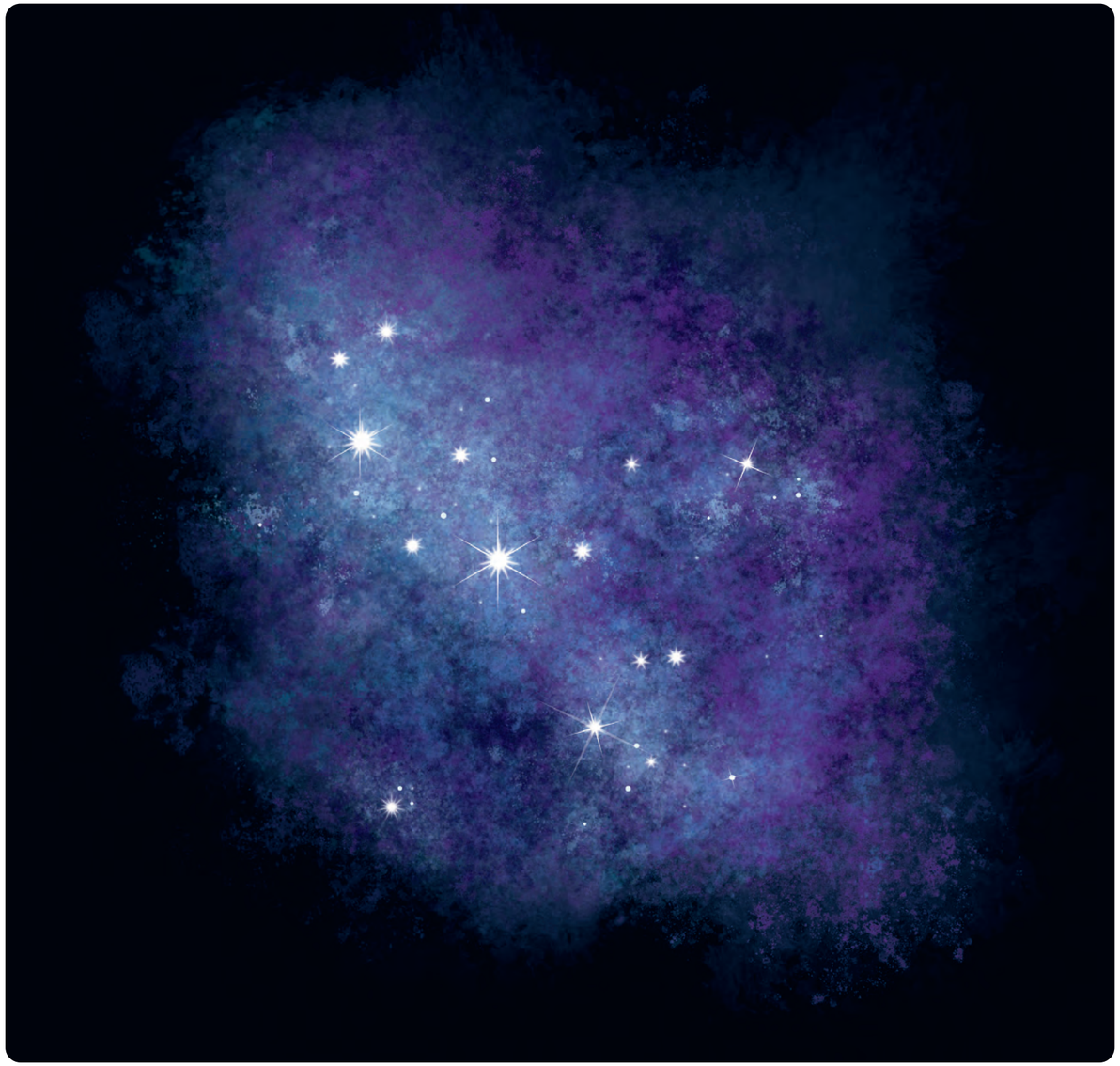
The Big Bang

13.8 billion years ago, what we now call the Big Bang occurred. This colossal explosion, however, didn't start at a specific place. It happened everywhere, all at once. In that single moment, space, as well as matter and time, came into existence.

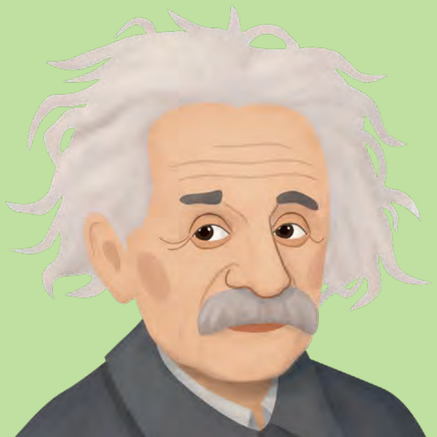
10^{-35} seconds after the Big Bag, the universe expanded rapidly.

At 10^{-32} seconds, the first particles appeared.

At first, the universe was dark. Then, about 380,000 years later, it became clear and filled with the fading heat from the Big Bang.

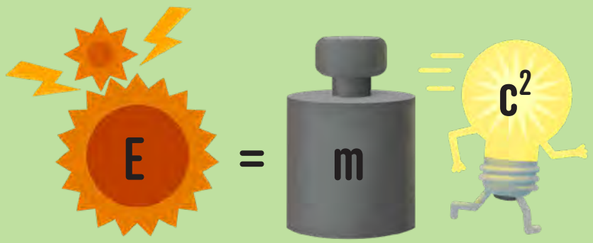


▲ First light



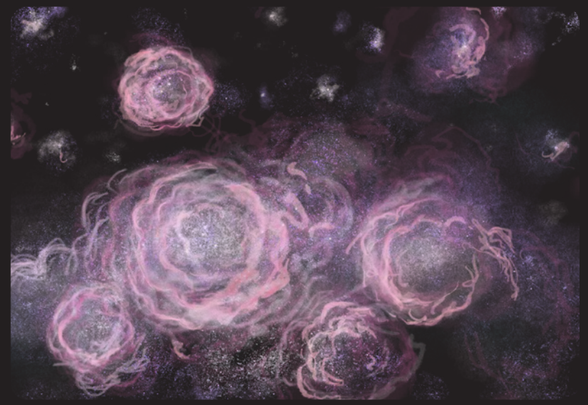
Albert Einstein

The brilliant scientist Albert Einstein (1879–1955) originally thought the universe was static, meaning it wasn't getting any bigger or smaller. But his original idea, called the General Theory of Relativity, showed that this wasn't true. To make his equations work, he added an extra number, which he later called the biggest mistake of his life. This was because other scientists would later discover the universe was actually expanding, and that extra number wasn't needed. Despite the mistake, it's a reminder that even great scientists can learn from their errors, leading to new discoveries.



The famous equation

Einstein came up with an amazing idea called the Special Theory of Relativity, which is explained with his famous equation $E = mc^2$. This simple little formula is like a special set of rules that explains how things change when they move really fast. This theory tells us that time can act differently for things that are zooming around, and it helps scientists understand the way our universe works, especially when things are moving super fast.



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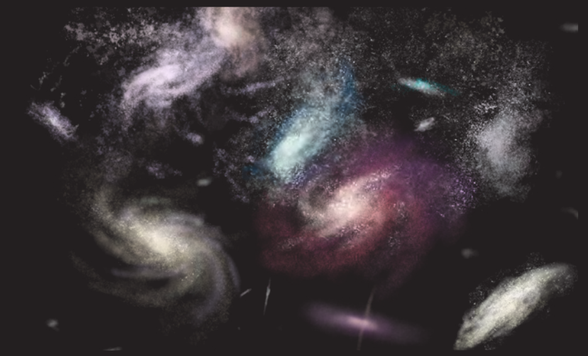
1. The first stars
About 300 million years after the Big Bang, the first stars in the universe were formed.



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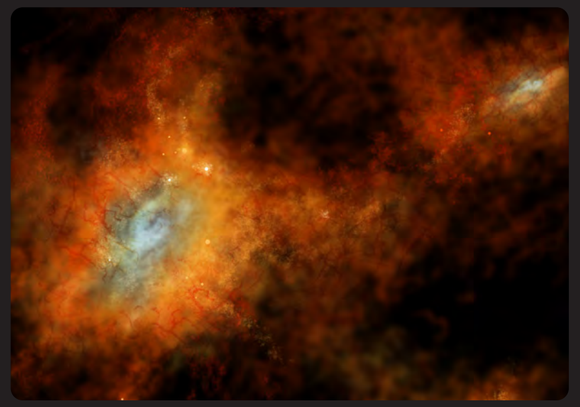
2. The birth of galaxies
Just under a billion years after the Big Bang, the first galaxies began to form in the universe.



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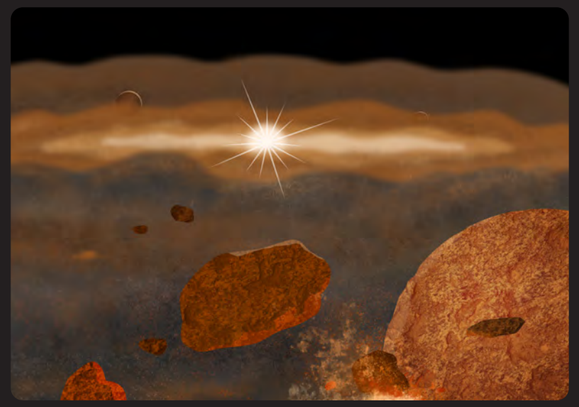
3. The formation of our Solar System
In the circa 9.1 billion years old universe, a nebula of dust and gas formed and then went on to turn into our Solar System.



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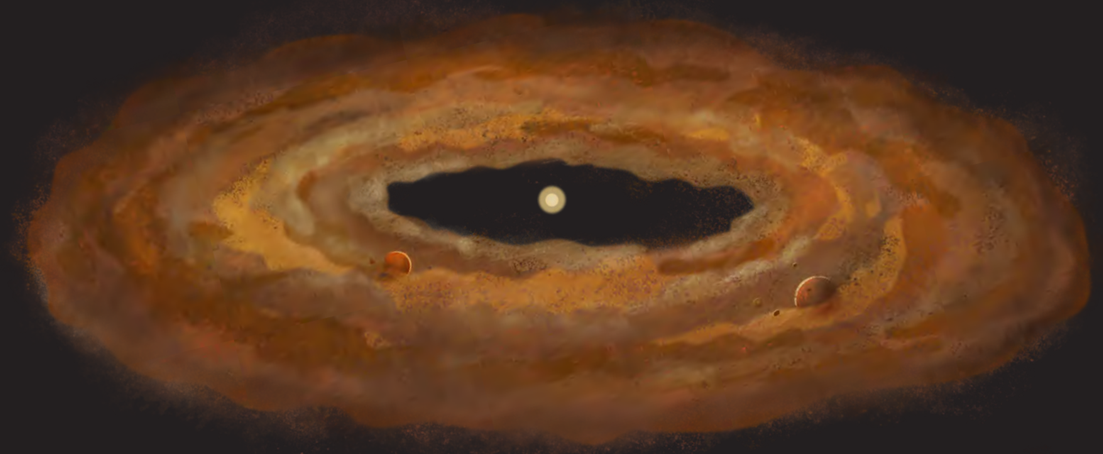
6. The Earth and her sisters are born
Approximately 50 million years after the Sun began shining, the planets Mercury, Venus, and Mars formed, as well as our Earth and Moon.



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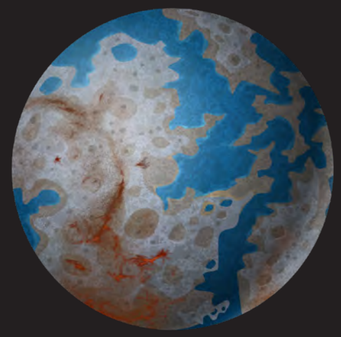
4. The seed for big planets is planted
4.59 billion years ago, the seed was planted for the future large planets: Jupiter, Saturn, Uranus, and Neptune.

5. The Sun becomes a star
Our Sun first came about roughly 4.55 billion years ago.

▼



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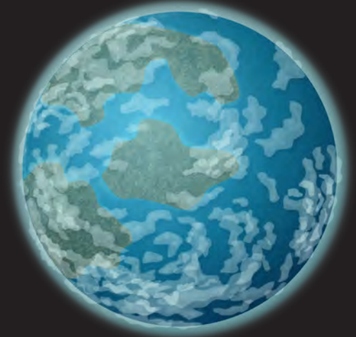
7. Life on Earth
About 3.8 billion years ago, the first primitive life appeared at the bottom of the Earth's oceans.



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8. A breathable atmosphere
Around 2.5 billion years ago, animals that live because of sunlight (called *photosynthetic organisms*) evolved on Earth, making oxygen, which mixed with other gases to form the air we breathe today.

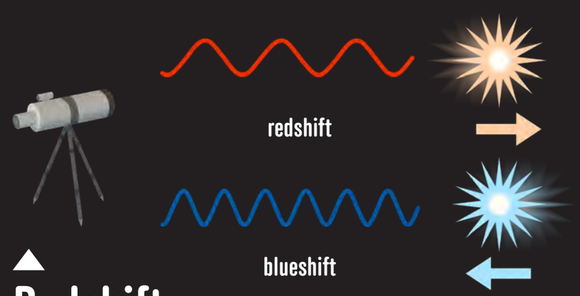
▲

9. The present day
Roughly half a billion years ago, more complex animals (called *multicellular organisms*) spread rapidly across the Earth. Most of the first fossils of all known animal groups ever found come from this period.

STARRY ISLANDS

Whirlpool galaxy

The view of the Whirlpool Galaxy M51, using various astronomy tools. Left: an ultraviolet image taken by the Spitzer Space Telescope. Middle: a visible light image taken by the Hubble Space Telescope. Right: an X-Ray image taken by the Chandra X-Ray Observatory.



Redshift

Since the universe is expanding, light from distant galaxies has a longer wavelength (like the above red wave). It's like how when you pull on a slinky toy, the coils get longer. Light waves are the same. The farther away a galaxy is from us, the faster it is moving away from us, and the longer its wave gets (called *redshift*). If an object is moving towards an observer, though, its wavelength gets smaller (called *blueshift*).

Black hole

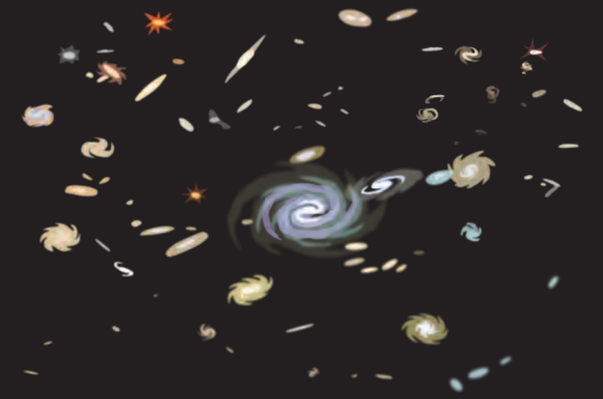
This is an image of a supermassive black hole, located in the middle of the M87 galaxy. The black hole itself isn't visible; the dark spot in the middle is just its shadow. It's surrounded by a thin gas whose radiation has reached Earth. That's why its center isn't totally black.

Our galaxy

The Milky Way is the galaxy we live in. It contains all the stars you can see without a telescope, including our Sun, which orbits the Galactic Center of our galaxy about 26,000 light years away. It looks thin when seen from the side, with a thickness of only about 1,000 light years. But it's 200,000 light years wide and contains about 500 billion stars.

Elliptical galaxies

Elliptical galaxies are some of the largest starry islands in the universe, though they're not as impressive as their spiral siblings – that's because they have no arms. The above image shows the huge elliptical galaxy M87 in the Virgo constellation, located 54 million light years away from us.

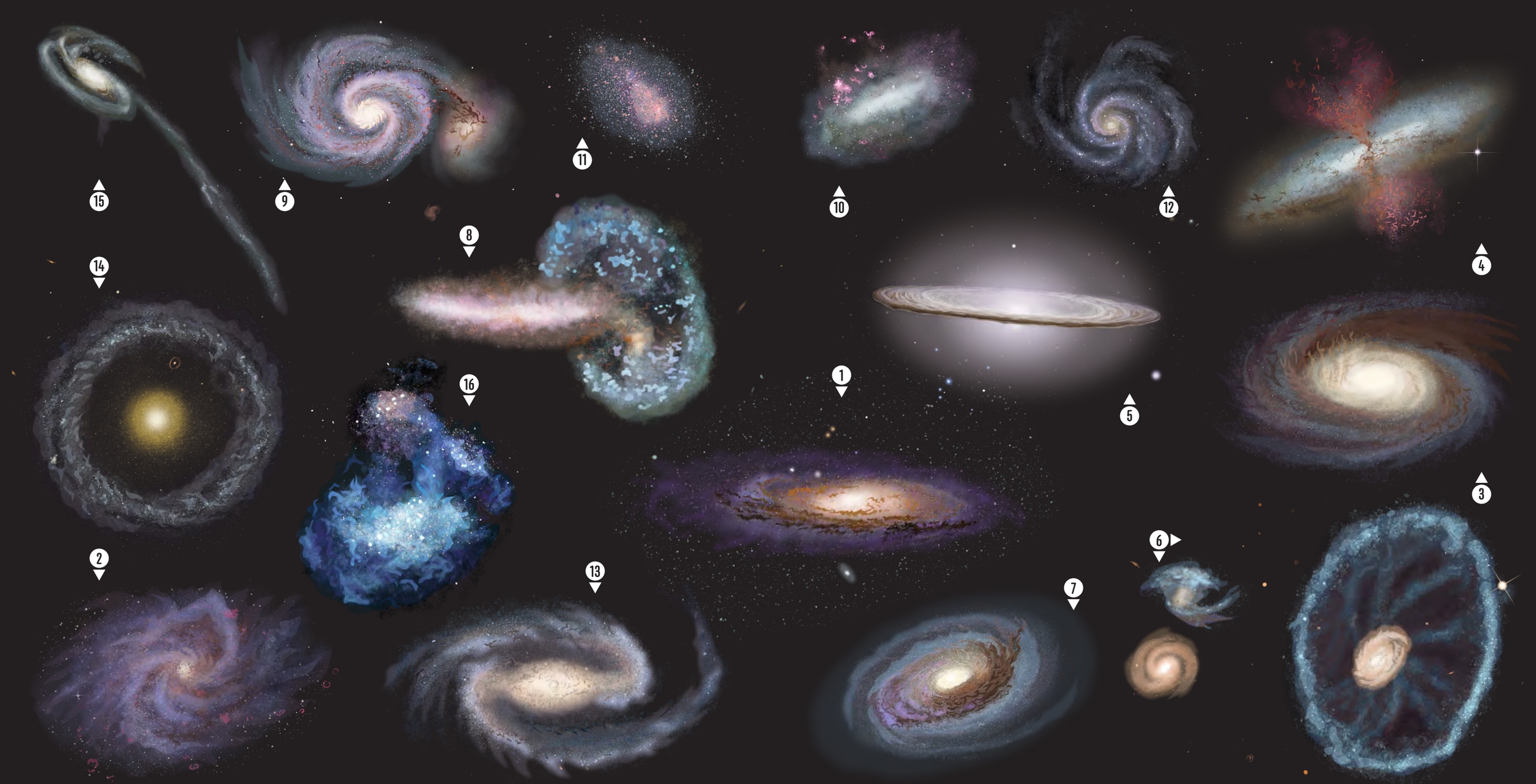


Galaxy cluster

Galaxies don't like to be alone. Most galaxies are bound by gravity to other galaxies, forming clusters. Small clusters can have dozens of galaxies, while large clusters can have thousands of galaxies, spread out over millions of light years!

Edwin Hubble

In 1609, when the Italian astronomer Galileo Galilei looked through his telescope, he was amazed to find thousands of stars in the hazy Milky Way. The vague gleam that up until then was considered nothing more than a foggy seam in the night's sky broke into thousands of stars. Thus, Galileo found out that we live in the middle of a huge starry island – a galaxy. Over time, astronomers found new clouds, some of which were dust clouds in our galaxy and others that weren't nebulae at all. One of these was the Andromeda Nebula. In 1923, U.S. astronomer Edwin Hubble discovered it was actually a very distant galaxy, similar to ours.



1. Galaxy M31 – Visible to the naked eye, the Andromeda Galaxy is located approximately 2.5 million light years away from us.
2. Galaxy M33 – Located roughly 3 million light years away from us, it's one of the most remote objects visible to the naked eye.
3. Galaxy M81 – The light of this galaxy takes 12 million years to reach us.
4. Galaxy M82 – This special irregular galaxy can be found near Galaxy M81.
5. Sombrero – Due to its prominent dust ring, Galaxy M104 looks sort of like a hat – specifically a wide-brimmed straw hat worn in Mexico, called a *sombrero*.

6. Cartwheel Galaxy – This single galaxy formed when two galaxies collided. Their arms broke down and created spokes connecting the outer rims.
7. Black Eye – Galaxy M64, with a dust belt near its center, looks like a heavy-lidded eye.
8. Galaxy Arp 148 – This galaxy is the result of a collision of two large starry islands located roughly 500 million light years away from us.
9. The Whirlpool Galaxy – Galaxy M51 is one of the most beautiful formations you can observe with a telescope.

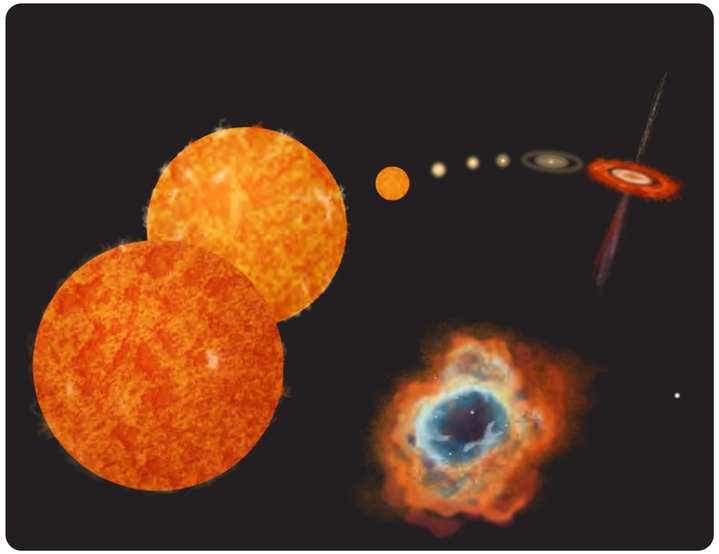
10. The Large Magellanic Cloud – A close neighbor of our own galaxy, it can be seen only from the southern hemisphere.
11. The Small Magellanic Cloud – It's located roughly 200,000 light years away from Earth, approximately 30,000 light years farther away than the Large Magellanic Cloud.
12. Pinwheel – The M101 is a face-on galaxy, meaning we can admire its arms to our heart's content.
13. Galaxy with a bar – The NGC 1300 galaxy has a noticeable bar in the middle.

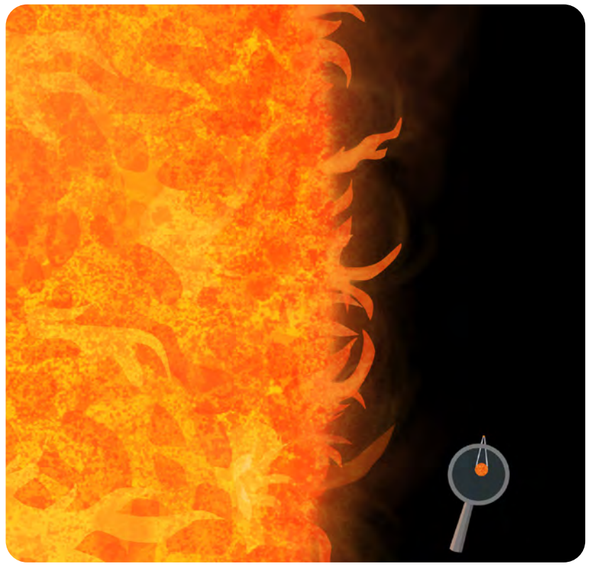
14. Hoag's object – A ring galaxy, it likely formed from the collision of two different galaxies.
15. Tadpole Galaxy – This galaxy's tail is 280,000 light years long and full of young stars.
16. Distant galaxy – An artist's rendition of one of the most distant galaxies, known as CR7. Its light takes 12.9 billion years to reach us!

THE REALM OF STARS

The lives of stars ▶

Astronomers study tons of stars in different stages of their life cycle. By watching so many stars, scientists can explain a star's journey through time, which depends mostly on its mass. Mass refers to the weight of everything that makes up a star. It decides how big the star is and how brightly it shines. The more mass it has, the faster and more dramatic its end will be. Our Sun is now in its prime. In a few billion years, though, it will expand to become a red giant. Once it gets old, it will turn into a cooling white dwarf, surrounded by a shiny cloud made of gases.





▲ UY Scuti ▲ Sun

▲

Big boy star

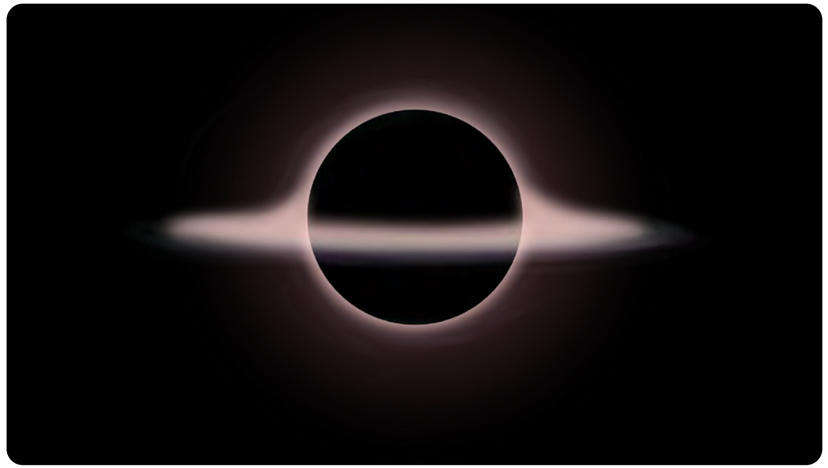
UY Scuti is a huge red hypergiant star in the Scutum constellation, located about 9,500 light years away from us. Our Sun would be a tiny speck compared to it – nearly a thousand times smaller!

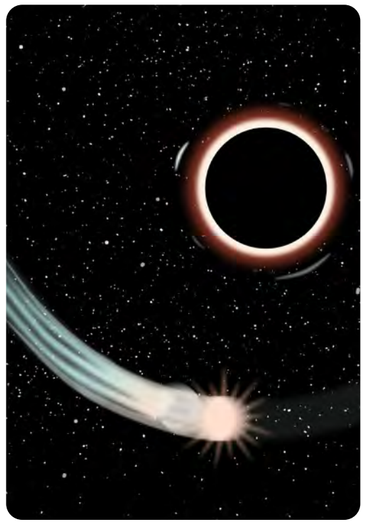
Inside the Sun ▼

Thermonuclear reactions take place inside the Sun at extreme temperatures and pressures, causing it to shine. Currently, the Sun is burning a gas called hydrogen and turning it into another gas called helium. Once the Sun has used up most of its hydrogen, it will start turning the helium into carbon, becoming a very large star at the end of its life, called a red giant. But don't worry – that won't happen for another 6 billion years.

Black holes ▶

The most massive stars in the universe face a harsh fate. When their outer layers can no longer bear the pressure, they collapse and form what is called an *event horizon*. The star implodes, creating a black hole from which nothing can escape – not even light itself.





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The fastest star

There's a supermassive black hole at the center of our galaxy, whose gravity affects the behavior of nearby stars. One of the stars, named S2, orbits the black hole at a whopping speed of 5,000 miles per second! If you were able to go that fast, you'd orbit Earth in just five seconds!

The coldest nebula

Stars can be hot, but sometimes they can also create cold. The Boomerang Nebula is a great example of this. In its center is a star that releases gases at a rapid speed, cooling the surrounding nebula to an incredible temperature of -458°F, just two degrees above absolute zero – the lowest possible temperature!

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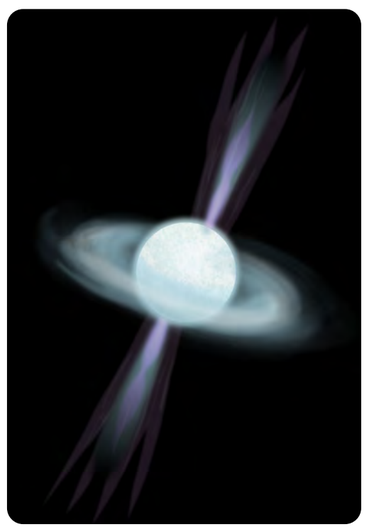

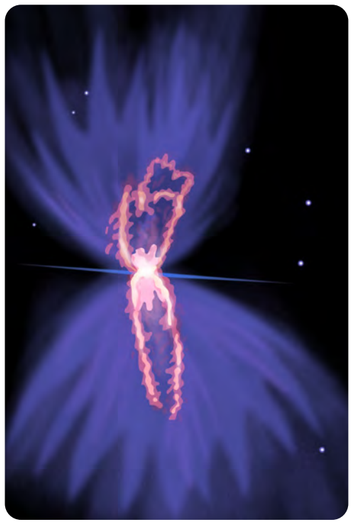

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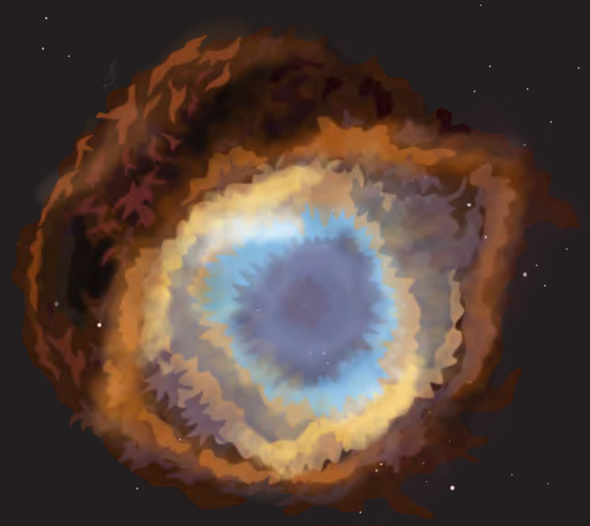
Neutron star

When a star explodes into a supernova, its core is left behind with a huge amount of compressed matter. This is called a *neutron star*. Imagine a sugar cube with more mass than a bunch of cargo ships – that's how dense neutron stars are. They're also known for their rapid rotation, with some spinning up to 700 times per second!



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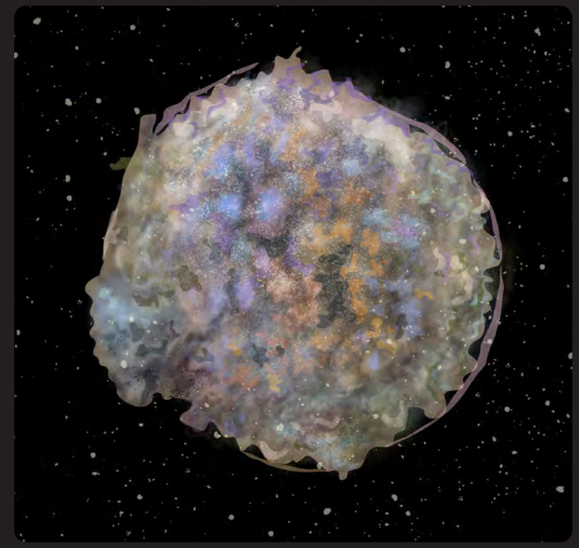
Helix Nebula
The glowing gas around a star, also known as a planetary nebula.

▲
Horsehead Nebula
A cloud of dust and gas in the Orion constellation.

▲
Omega Nebula
It's likely that new stars are also forming in this nebula in the Sagittarius constellation.



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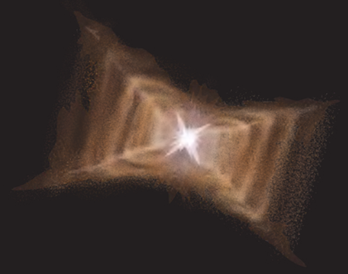
Tycho's supernova
Remnants of an explosion observed in 1572 by the Danish astronomer Tycho Brahe.

▲
Pillars of Creation
A nebula in the Eagle constellation where new stars are forming.

▲
White dwarf
One of the final stages of a star's life cycle. The Sun will go through this stage too.

▲
Blue giant
This type of star can have up to 150 times more mass than the Sun.



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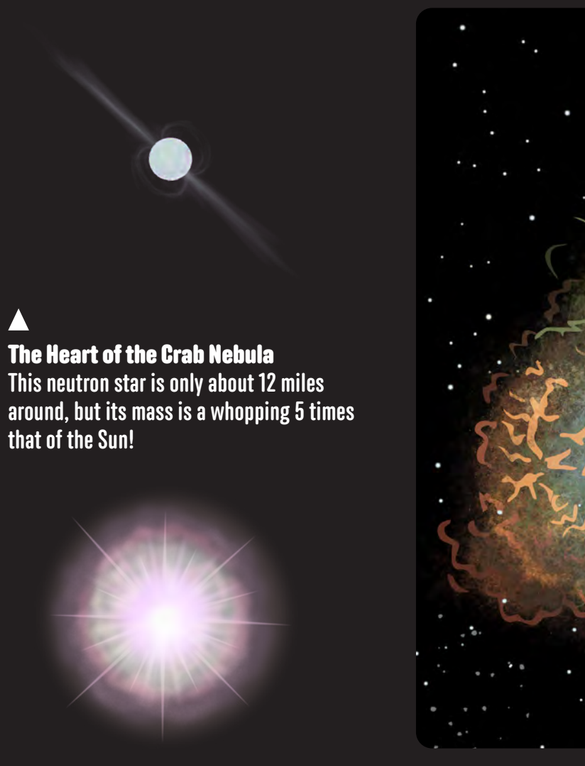
Red Rectangle Nebula
An unusual planetary nebula.



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The Heart of the Crab Nebula
This neutron star is only about 12 miles around, but its mass is a whopping 5 times that of the Sun!

▲
Supernova explosion
The Crab Nebula formed during the explosion of a supernova in 1054.

▲
Crab Nebula
Remnants of a supernova explosion in the Taurus constellation.

CONSTELLATIONS

Northern sky

If you stand on the icy North Pole, you can only see half of the sky – the northern half. As you move south, more and more of the southern sky will reveal itself to you.

Southern sky

At the equator, you can see both the northern and southern sky all year round. In Antarctica, only the southern sky is visible.

Claudius Ptolemy

People have been giving names to groups of stars since ancient times. These names were usually of gods, mythical heroes, or everyday objects. The most famous names come from the constellations described by the Greek astronomer Claudius Ptolemy in 148 CE. It wasn't until 1930 that the International Astronomical Union tidied things up and introduced the 88 constellations we know today.

Leo – This constellation really does look like a resting lion, with the bright star Regulus for its heart.

Boötes is a northern constellation that includes the distinct star Arcturus. It is considered to be the guardian of the Ursa Major and Ursa Minor constellations.

Sextans – A small constellation, named after the sextant – a tool for measuring angles in the sky.

Draco – A large constellation that never goes down in the northern hemisphere.

Ursa Minor – Also known as the Little Dipper. It includes the North Star, which, in the northern hemisphere, shows where north is because it always stays in the same spot in the sky, like a celestial compass.

Ursa Major – The seven brightest stars of this large constellation make up the well-known formation called the Big Dipper.

Cassiopeia – An easily recognizable W-shaped constellation in the northern sky.

Corona Borealis – A small constellation that looks like a crown with an inset jewel – its brightest star is Gemma.

Taurus – This Latin name, meaning *Bull*, refers to a very distinct constellation containing the reddish star Aldebaran, which is visually like the bull's eye.

Orion is one of the most stunning constellations in the night sky. It's easy to spot because of the three bright stars that form its belt.

Cancer – An inconspicuous constellation with the open Beehive Cluster, which, when the skies are clear, can be seen without a telescope.

Lepus – Also called the Hare. It can be found near Orion, a figure who hunts hares.

Monoceros – A modest constellation near Orion.

Cetus – The fourth biggest constellation in the sky. It symbolizes a sea monster sent by the god Poseidon.

Pegasus – A constellation named after a mythical winged horse, the son of Poseidon and Medusa.

Capricornus – One of the less distinct zodiac constellations, named after the Greek god of pastures and forests.

Perseus – A distinct constellation in the northern sky. Every year, the Perseids, a spectacular meteor shower, appears near it in late summer. The mythical Perseus famously chopped off the head of the monstrous Medusa, who had snakes for hair.

Sagittarius – A zodiac constellation that includes the brightest – and the most beautiful, many believe – part of the Milky Way.

Cygnus – A beautiful northern constellation shaped like a swan. Its Latin name even means "swan." According to legend, the god Zeus could transform into a swan to walk among humans.

Delphinus – An adorable constellation that looks like a dolphin. According to Greek legend, a dolphin once saved the life of the poet Arion, who had been thrown into the sea by sailors.

Crux – A distinct constellation in the southern sky. It includes a bright part of the Milky Way and is the smallest of the 88 constellations.

Tucana – A modern constellation introduced by Dutch seafarers in the 17th century. It depicts a South American bird with a big, colorful beak.

Columba – A hidden little constellation that symbolizes a biblical dove holding an olive leaf in its beak.

Phoenix – A southern constellation that depicts the mythical fiery bird called the Phoenix.

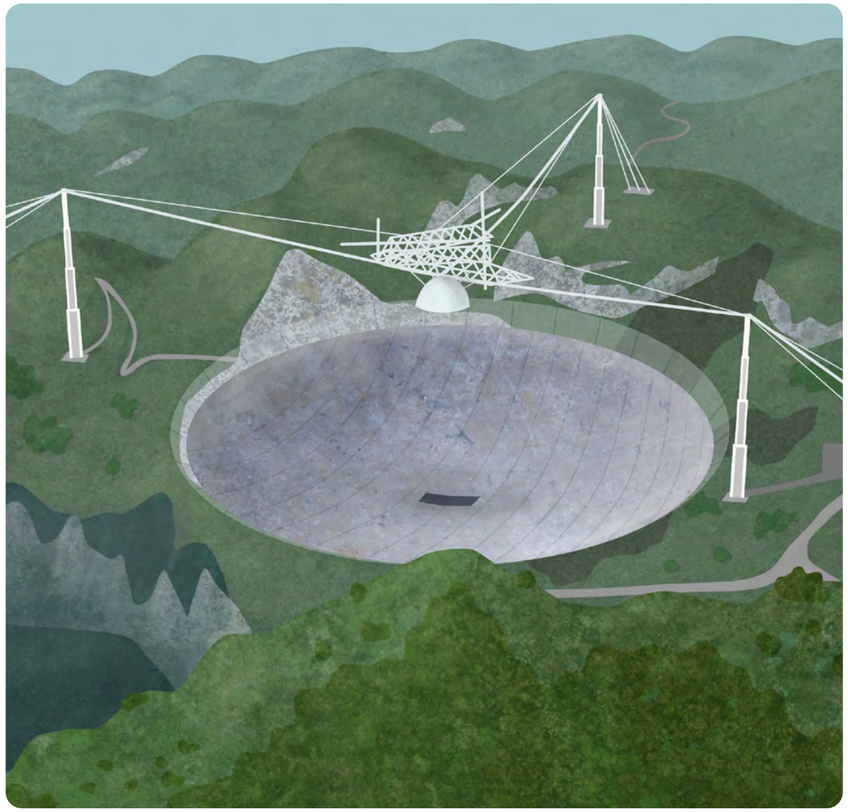
Volans – A quaint constellation named after a flying fish whose fins enable them to glide across the surface of water.

Pyxis – A small constellation that was named by French astronomers in 1754.

OBSERVING THE UNIVERSE

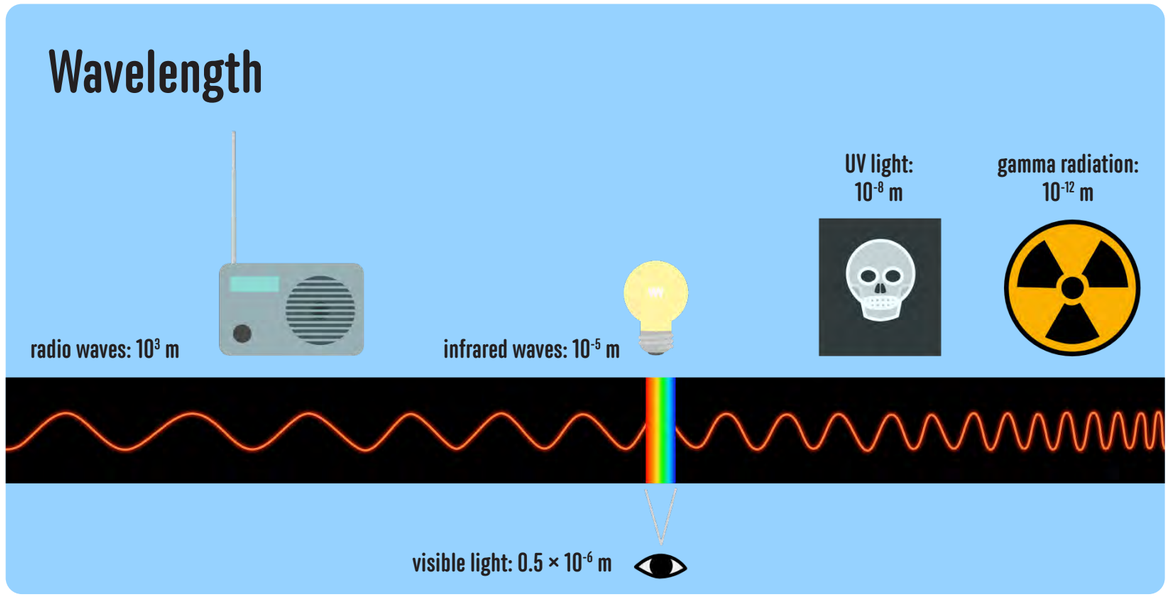
Observing the universe

We can observe the universe using different kinds of waves, like radio waves, microwaves, infrared waves, visible waves, ultraviolet waves, X-rays, and gamma radiation. The Arecibo Observatory in Puerto Rico used to be the biggest radio observatory in the world, but sadly its telescope collapsed in 2020.



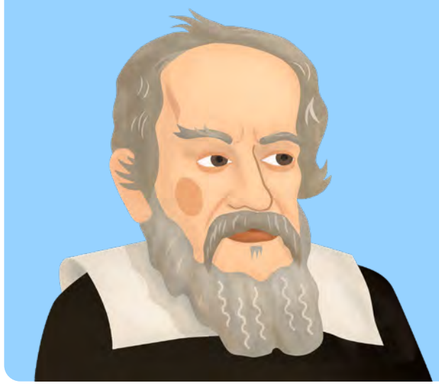
Radioteleskop Arecibo
1963–2020

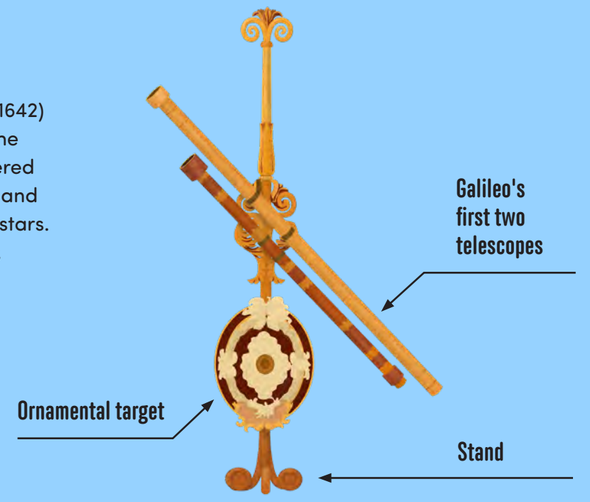
Wavelength



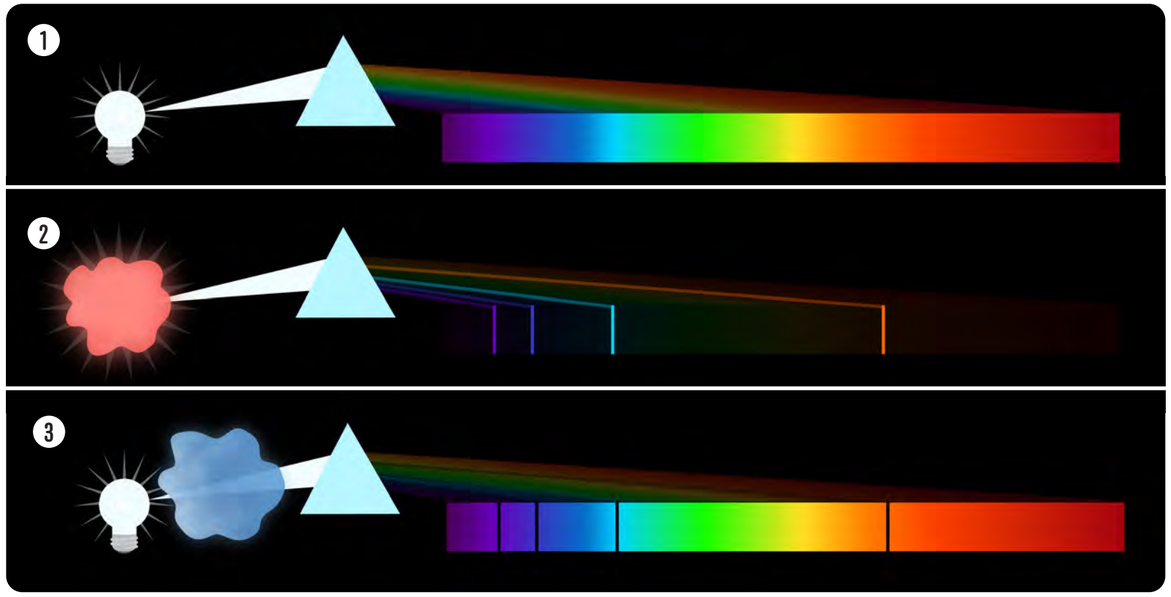
Galileo Galilei

In 1609, the Italian astronomer Galileo Galilei (1564–1642) built a telescope and was one of the first people in the world to use one to observe the universe. He discovered the craters on the Moon and four of Jupiter's moons and found out that the Milky Way was made up of many stars. He wrote a small book called *The Starry Messenger*, which was read all over Europe.





Galilei's telescope would seem simple by modern standards. It had lots of optical flaws and could make things look only 20 times bigger. Even so, the Italian scholar managed to use it to make some amazing discoveries that were completely new for his time.



The Light Spectrum

With a special glass triangle, we can split light into different colors like a **rainbow (1)**. When light comes from a shiny thing like the northern lights, it makes **lines of colors (2)** that tell us about the elements in it. If light goes through a gas, it makes **dark lines (3)** that help us know what's in the universe. Astronomers use this to figure out how hot stuff is and what stuff is out there in space.

1. Holmdel Horn Antenna (1959)
Diameter of 20 feet

2. Super-Kamiokande Neutrino Detection Experiment (1983)

3. Hubble Space Telescope (1990)
Diameter of 8 feet

4. Solar and Heliospheric Observatory spacecraft (1996)

5. Chandra X-Ray Observatory (1999)
Diameter of 4 feet

6. Spitzer Space Telescope (2003)
Diameter of 2.5 feet

7. Gran Telescopio Canarias (2007)
Diameter of 34 feet

8. Kepler Space Telescope (2009)
Diameter of 3 feet

9. Atacama Large Millimeter Array (2011)
66 radio telescopes,
diameter of 40 and 22 feet

10. James Webb Space Telescope (2022)
Diameter of 21 feet

11. Extremely Large Telescope (2027)
Diameter of 128 feet

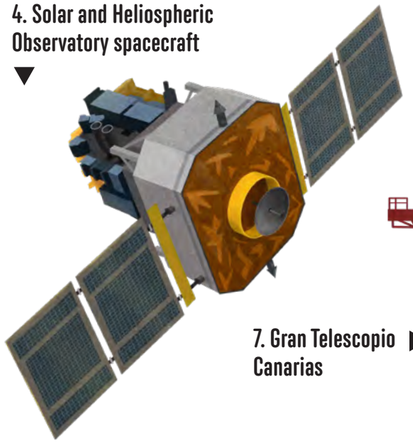
12. Simple *refracting* telescope (using lenses to gather and bend light)

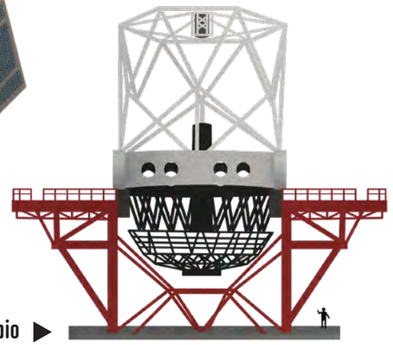
13. Simple *reflecting* telescope (using mirrors to bounce and focus light)

14. Astronomical observatory

Note: The sizes of the individual telescopes and observatories here are not shown in relation to one another. Some of this stuff is very big, and some is very small.

4. Solar and Heliospheric Observatory spacecraft ▼



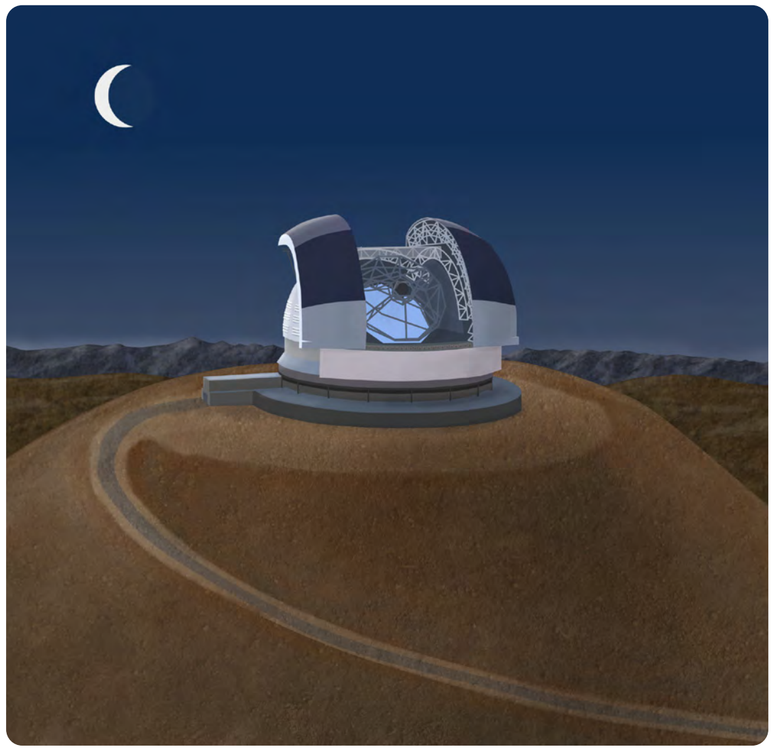


7. Gran Telescopio Canarias ▶

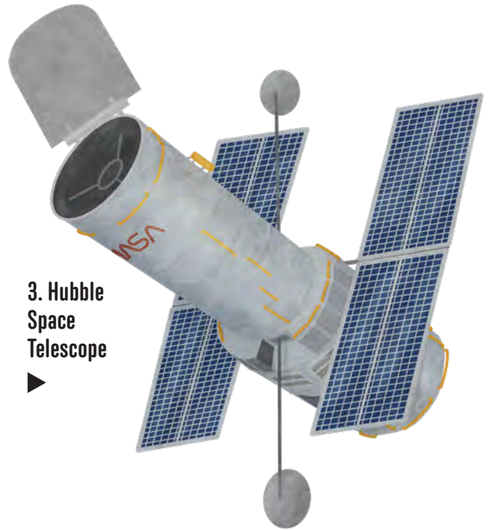
14. Astronomical observatory ▼

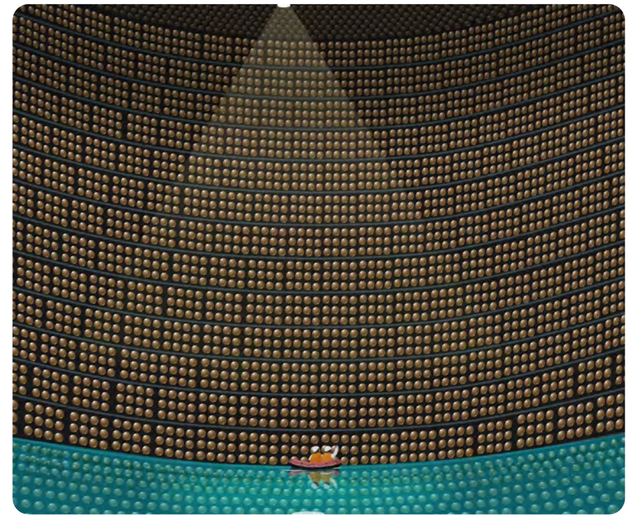
10. James Webb Space Telescope ▼

11. Extremely large telescope ▼



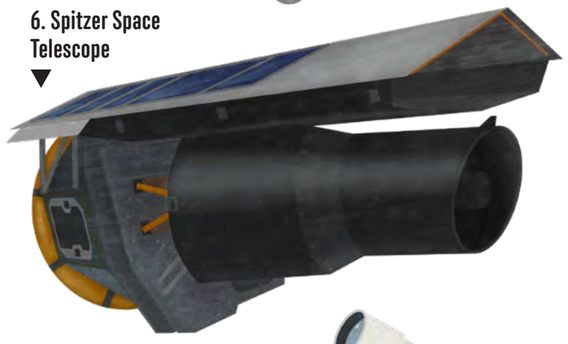
3. Hubble Space Telescope ▶

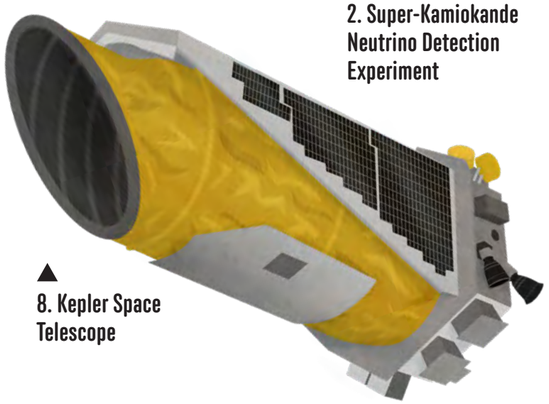




▲ 2. Super-Kamiokande Neutrino Detection Experiment

6. Spitzer Space Telescope ▼



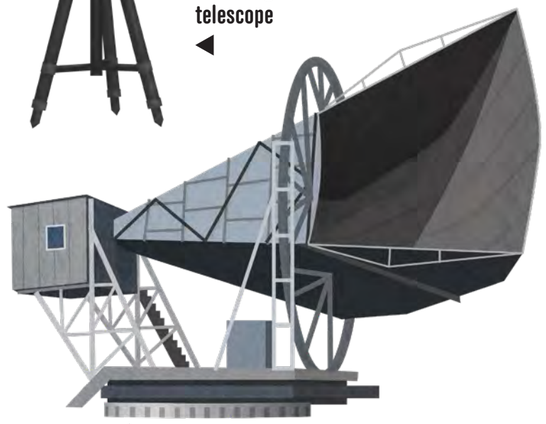


▲ 8. Kepler Space Telescope

12. Simple refracting telescope ▶

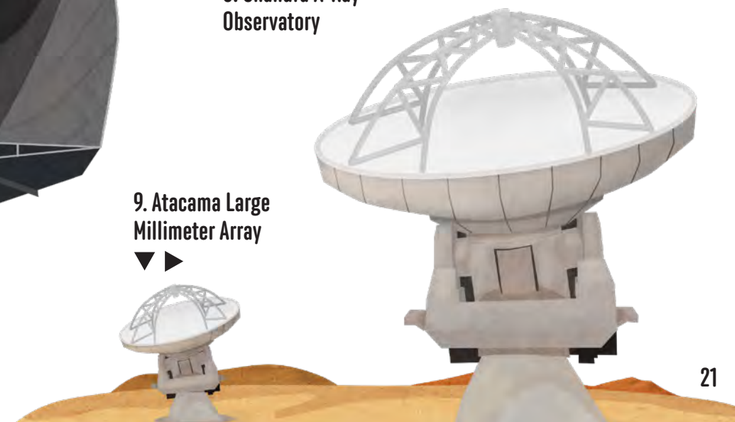
13. Simple reflecting telescope ◀

▲ 5. Chandra X-Ray Observatory



▲ 1. Holmdel Horn Antenna

9. Atacama Large Millimeter Array ▼ ▶



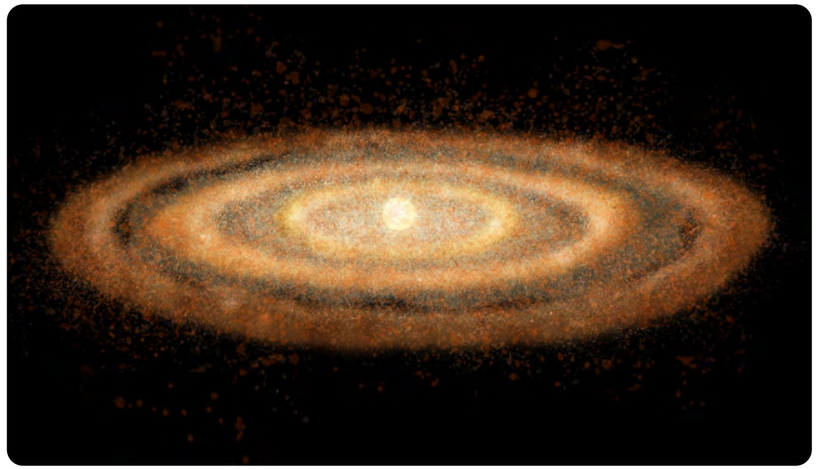
THE SOLAR SYSTEM

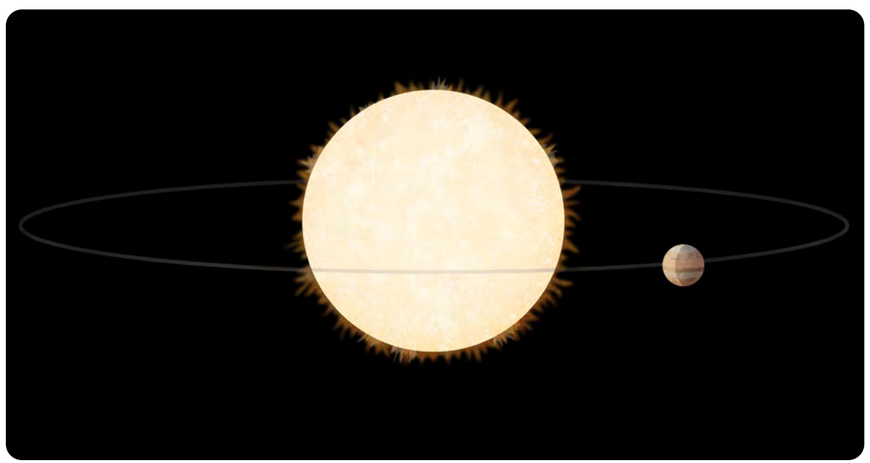
Nicolaus Copernicus

The Polish astronomer Copernicus (1473–1543) presented evidence that Earth was a planet orbiting the Sun, contradicting the prior belief that Earth was the center of the universe. His ideas were seen as heretical by the Catholic Church and were only accepted by the world a century after his death.

The Origin of the Solar System ▶

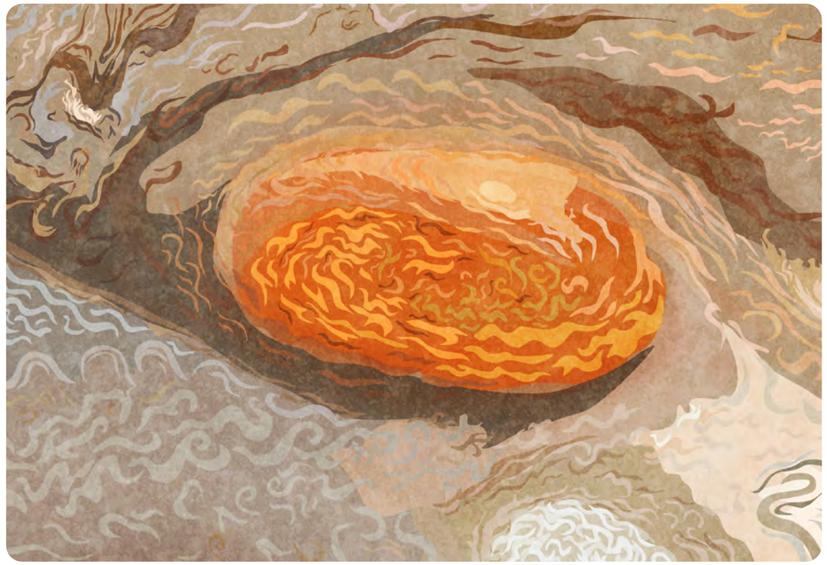
Our solar system formed about 4.5 billion years ago from a large cloud of gas and dust. The first objects to appear were *proto-planetary* objects, also known as ***planetesimals***, which then attracted more and more matter until they turned into large planets.





What is a planet?

A planet – like ours, Planet Earth – is an object that orbits the Sun and has enough mass for its gravity to push away anything in its path. Planets don't give off their own light, they just reflect the Sun's light.

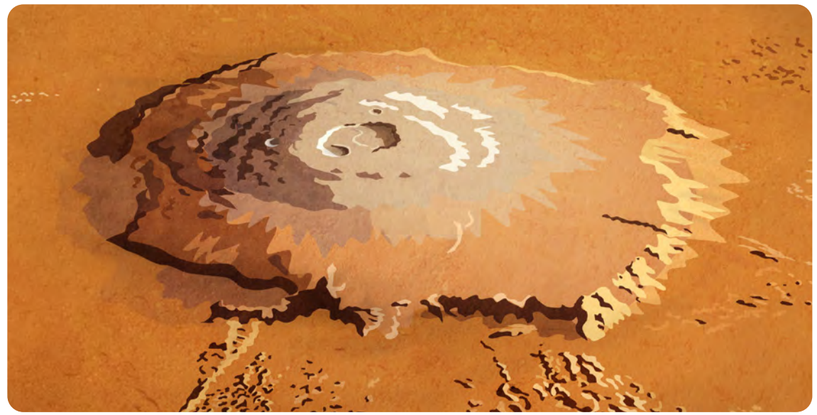


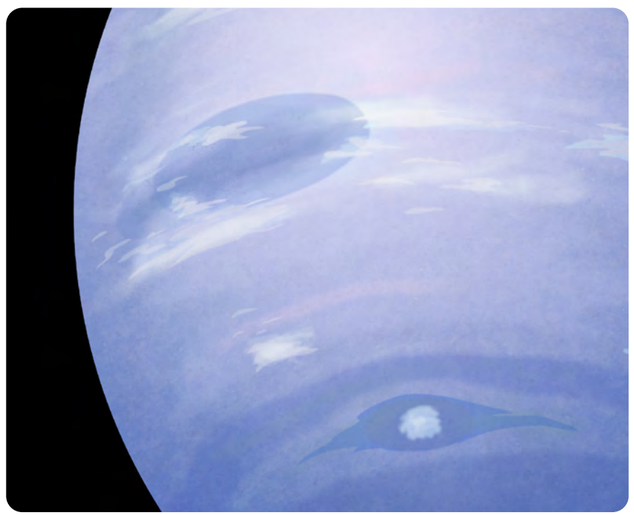
Great Red Spot

Jupiter is a stormy planet, with the Great Red Spot being its most impressive storm. This raging storm has been observed for at least 350 years, with winds blowing at around 400 miles per hour. Its size is truly awe-inspiring, measuring over 12,400 miles across – bigger than the Earth!

Olympus Mons ▶

The biggest volcano in the Solar System is on Mars. It stands over 16 miles high, towering over the landscape! On Earth, this enormous volcano would take up almost the whole of France.



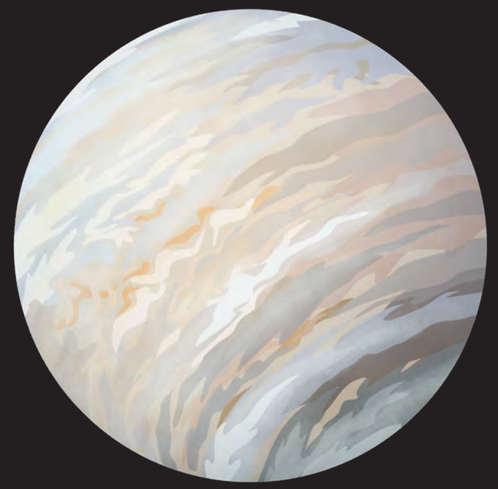


The fastest planetary wind

The strongest winds in the Solar System are found on Neptune. In 1989, astronomers observed an enormous vortex in the planet's atmosphere and named it the Great Dark Spot. This "eye" was as wide as our entire planet and the wind blew at a speed of over 1,550 miles per hour! Although the Great Dark Spot has since disappeared, Neptune still experiences winds that move the clouds at over 620 mph.

▲

Mercury
The smallest planet and the one closest to the Sun.
Diameter: 0.4 of Earth



▲

Venus
A planet perpetually shrouded in clouds.
Diameter: 0.9 of Earth

Minor planets ▶
There are millions of them in the Solar System.
Diameter: up to 0.07 of Earth

▲

Earth
Our home planet
Diameter: 7,915 miles

▲

Mars
A planet covered with red dust
Diameter: 0.5 of Earth

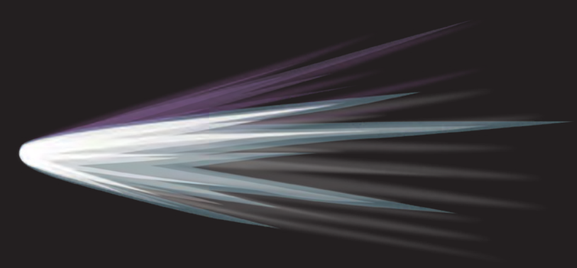
▲

Jupiter
The biggest planet in the Solar System.
Diameter: 11 Earths

▲

Saturn
The planet with the biggest rings.
Diameter: 9.4 Earths

Comets ▶
Bodies that mostly consist of ice.
Diameter: up to 0.1 of Earth



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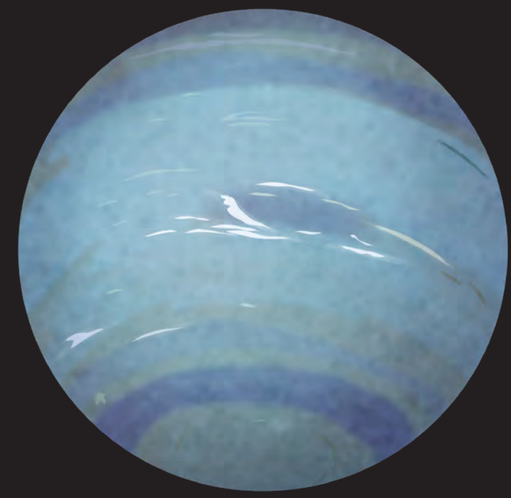
Uranus
The only planet that "rolls" along its trajectory – meaning its spins on its side as it orbits the Sun, unlike other the planets, which spin upright like tops.
Diameter: 4 Earths



▲

Neptune
The planet with the fastest winds.
Diameter: 3.8 Earths

AN EXCEPTIONAL PLANET

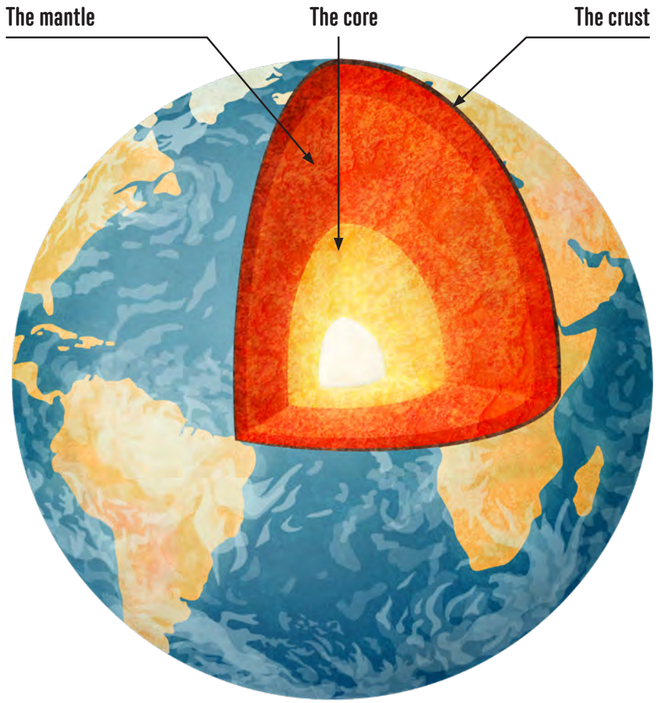
Blue planet

There's a reason Earth is the most appealing planet to us – the conditions here are perfect for advanced life forms (like us) to exist. It's the perfect place for you to read a book like this one, for example. When seen from outer space, Earth looks mostly blue, with some white and brown spots. The blue is from the oceans, which cover more than two-thirds of the planet. The white is from clouds and the polar ice caps. And the brown is from the continents.

The Earth's core

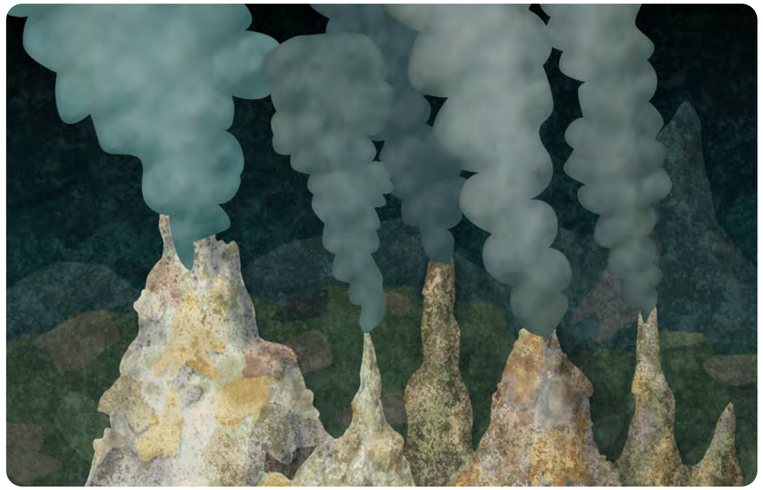
The things beneath our feet are very important. That's because our planet's core is constantly hot, which keeps it alive!

The Earth's top layer is called **the crust**. If our planet was the size of an apple, the crust would be thinner than the apple's skin. Below the crust is **the mantle**, which is filled with molten magma. Below that is the **Earth's core**, which is made up of two parts. The outer core is liquid and extends nearly 3,100 miles deep. The inner core is solid and incredibly hot, with temperatures exceeding 9,000 degrees Fahrenheit.



A protective envelope

Earth's gas envelope, known as the **atmosphere**, is especially important for life on Earth. Not only does it give us air to breathe, but it also maintains the right temperature and protects us against the dangers of outer space. It shields us from the deadly radiation of the Sun and from distant exploding stars. Moreover, the atmosphere destroys most of the cosmic debris that hits our planet all the time going really fast.



The Origins of life

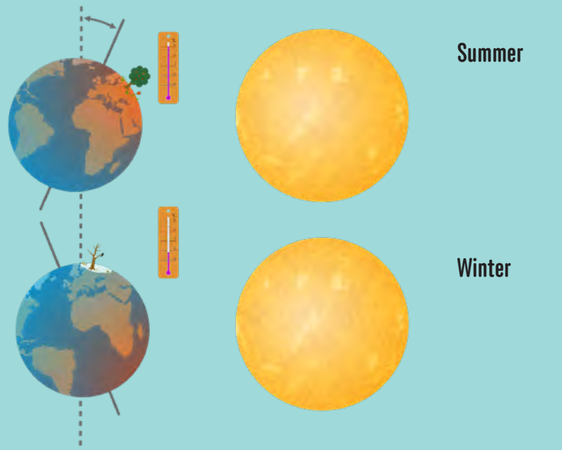
We still don't know if life on Earth came from outer space or if it formed here on Earth. But if life did come from Earth, then it likely came from deep-sea hydrothermal vents, known as **black** or **white smokers**, depending on the color of the water they release. These smokers are connected to Earth's core and provided oceans with the heat and minerals needed for simple life forms to develop.

Changing seasons

Our Earth is tilted at an angle as it orbits around the Sun. This is why we experience changing seasons. The further away from the equator you are, the more distinct the seasonal changes become. In the northern hemisphere summer is from June to August, while in the southern hemisphere it's from December to February.

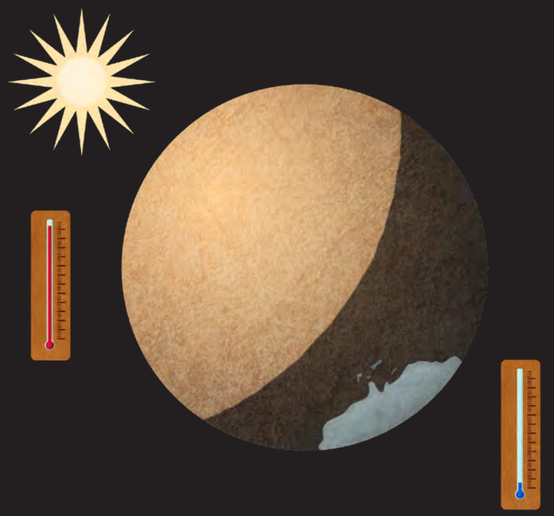
Summer: When the northern hemisphere is tilted toward the Sun, it's summer in the north.

Winter: When the northern hemisphere is tilted away from the Sun, it's winter in the north.



Mass extinctions

We live on a planet whose surface keeps changing. A long time ago, dramatic changes caused many plant and animal species to go extinct – life was in danger a lot back then! One of the most recent mass extinctions happened 66 million years ago. You've probably heard of it, since it's the one that killed off the dinosaurs. This was likely caused by an asteroid hitting Earth.

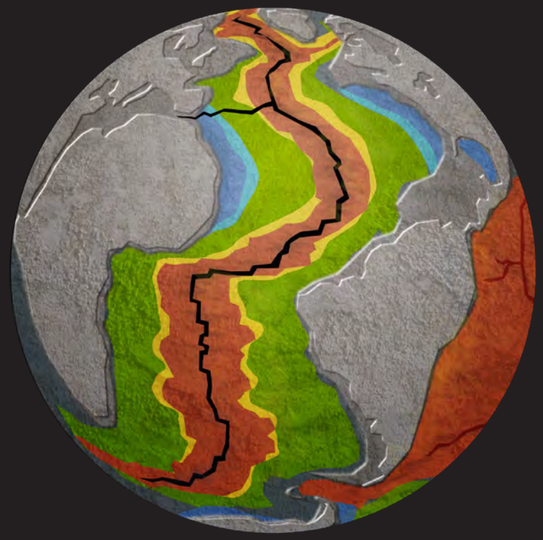


▲

Changing temperatures
Earth's atmosphere prevents temperatures from changing rapidly between day and night.

▲

Water in all states
On Earth, water can exist in all three states: solid, gas, and liquid.



▲

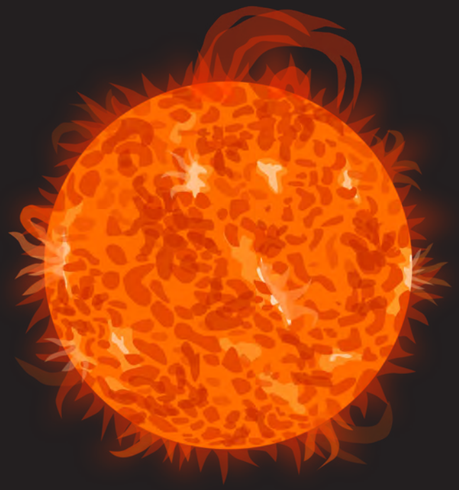
Continents on the move
The tectonic shifting of Earth's plates "recycles" the crust.

▲

The important Moon
Without the Moon, Earth's rotation axis would be volatile and our climate unstable.

▲

Magnetic field
This protects us from the charged particles coming from the Sun.



▲

Right star
Fortunately, the Sun is a calm, stable star that has been around a long time.

▲

The perfect distance from the Sun
If Earth was just a little bit closer to the Sun, it would be way too hot here; if it was further away, it would freeze solid.

PLANETARY FELLOWS

Jupiter's moons

In 1610, when the Italian astronomer Galileo Galilei looked through his telescope at Jupiter, he saw something incredible! There were four bright objects close to the planet, moving around over days. Galileo realized he had just made a revolutionary discovery – Jupiter had four moons orbiting it! Keep in mind, no one knew back then that planets could have moons. Now we know that Jupiter has at least 80 of them.

Christian Huygens

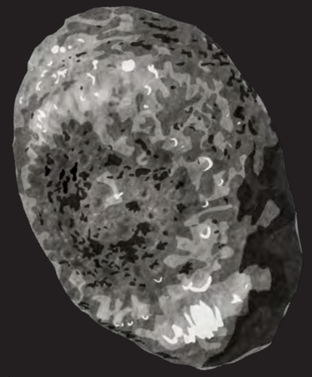
After Galileo discovered Jupiter's moons, Christian Huygens was the next to spot a moon, in 1655, near Saturn. The English astronomer John Herschel later named it Titan, which was fitting because it is Saturn's largest moon and the second largest satellite in our solar system – bigger than the planet Mercury, in fact!

Moons and satellites

Objects that go around planets or other big things in space are called moons or satellites by astronomers. Right now, we know of more than 200 moons around planets and hundreds of satellites around minor planets.

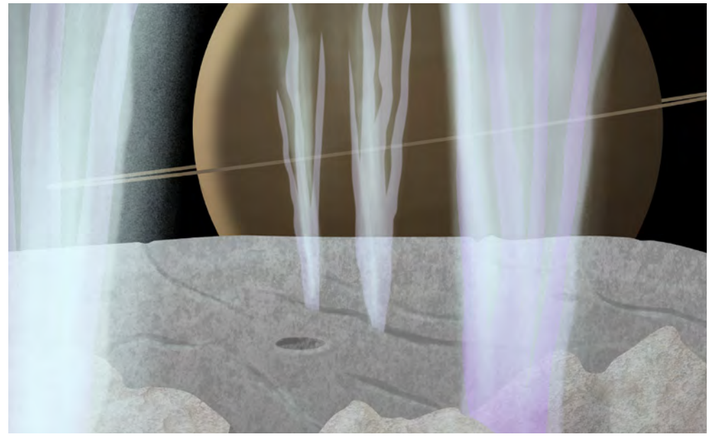
Like a flying saucer

Pan, a moon orbiting Saturn inside its rings, looks like a flying saucer. It's a beautiful work of nature, roughly 9 miles in diameter. One theory suggests its equatorial ridge is made of materials it "collected" from the surrounding rings. Another theory says it was created by the head-on collision of two smaller moons.



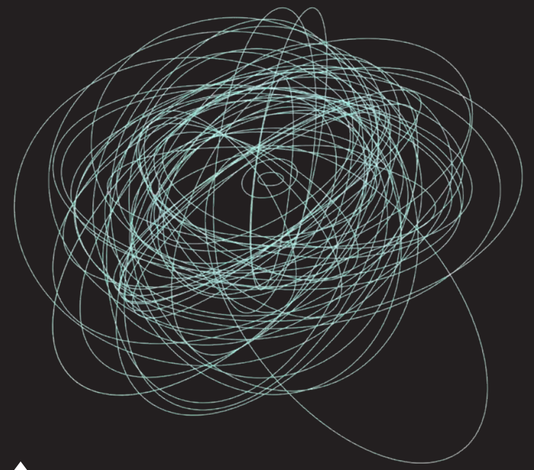
The holey moon

Hyperion is a unique moon orbiting Saturn at a distance of nearly a million miles away from it. Amazingly, almost half of its total volume is empty space. That means Hyperion is not just an ordinary rock, but something more like the center of an icy comet that is frozen forever.



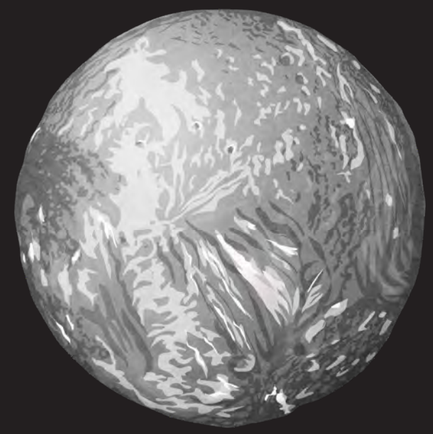
Ice fountains on Enceladus

In 2005, the Cassini probe found huge clouds of water escaping from the surface of Saturn's moon Enceladus. Enceladus is so freezing that as soon as water vapors spurt above the surface, they create a cloud of icy crystals that form into ice fountains. Most of this ice spray falls back onto the moon's surface in the form of snow, while some is released into outer space and becomes part of Saturn's outer rings.



Families of moons

While the rocky planets Mercury and Venus have no moons, our Earth has only one. Mars has two small ones and the gas giants Jupiter, Saturn, Uranus, and Neptune have dozens of them. Most of these moons are smallish objects that orbit along various tilted trajectories, sometimes contrary to their mother planet's rotation. This is what the trajectories of several of Saturn's moons look like.



The remarkable Miranda

Miranda is Uranus's fifth largest moon. It looks like it was broken into many pieces and then randomly put back together. Its surface is full of deep valleys, mountain ridges, cracks, long grooves, icy patches, and craters. We still don't know what caused Miranda to break.

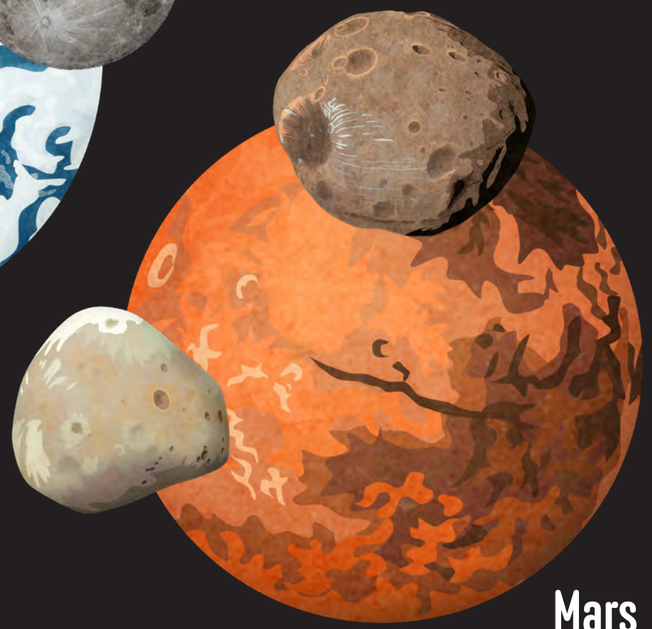
Earth

The Moon (diameter: 2,159 miles)
Humans have landed there.

Mars

Phobos (dimensions: 17 × 14 × 13 miles)
A satellite with a huge crater.

Deimos (dimensions: 10 × 8 × 7 miles)
A potato-shaped moon.



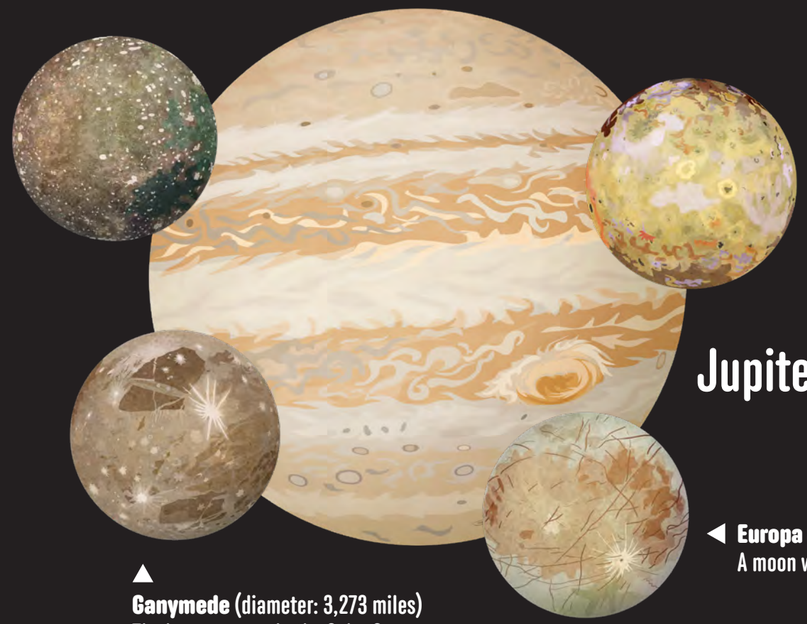
Jupiter

Callisto (diameter: 2,995 miles)
An ice moon with many craters.

Io (diameter: 2,263 miles)
A scorching moon with many volcanoes.

Europa (diameter: 1,949)
A moon with an ice shell, full of cracks.

Ganymede (diameter: 3,273 miles)
The largest moon in the Solar System.

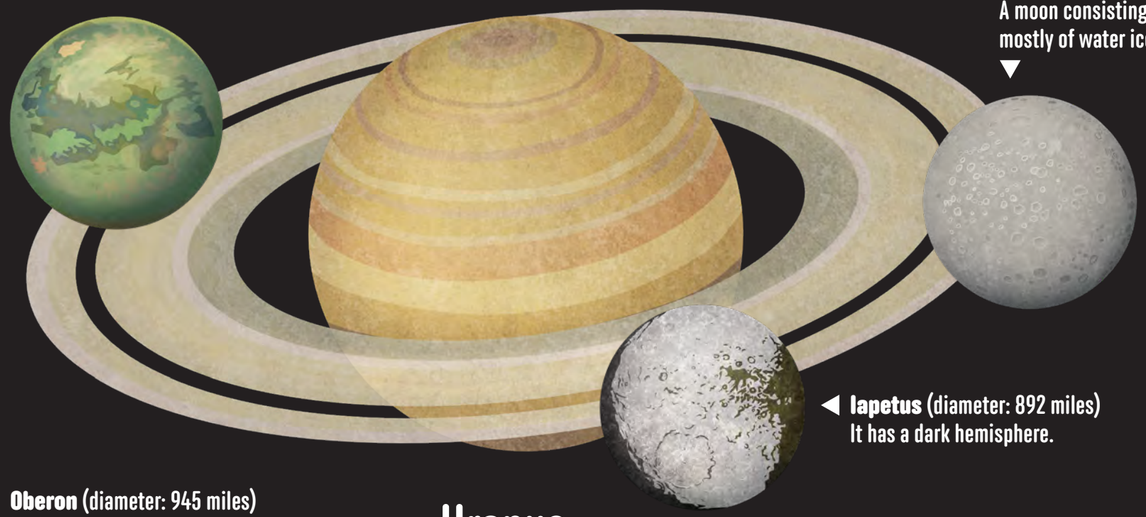


Saturn

Titan (diameter: 3,200 miles)
The only moon with a thick atmosphere.

Rhea
(diameter: 950 miles)
A moon consisting mostly of water ice.

Iapetus (diameter: 892 miles)
It has a dark hemisphere.



Uranus

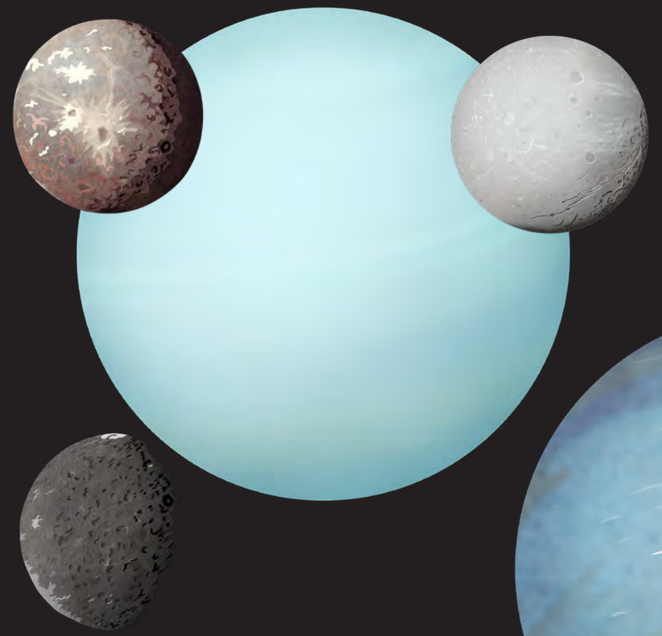
Oberon (diameter: 945 miles)
Made of ice and rocks.

Titania (diameter: 980 miles)
Uranus's largest moon.

Proteus
(diameter: 260 miles)
It has an unusually elongated shape.

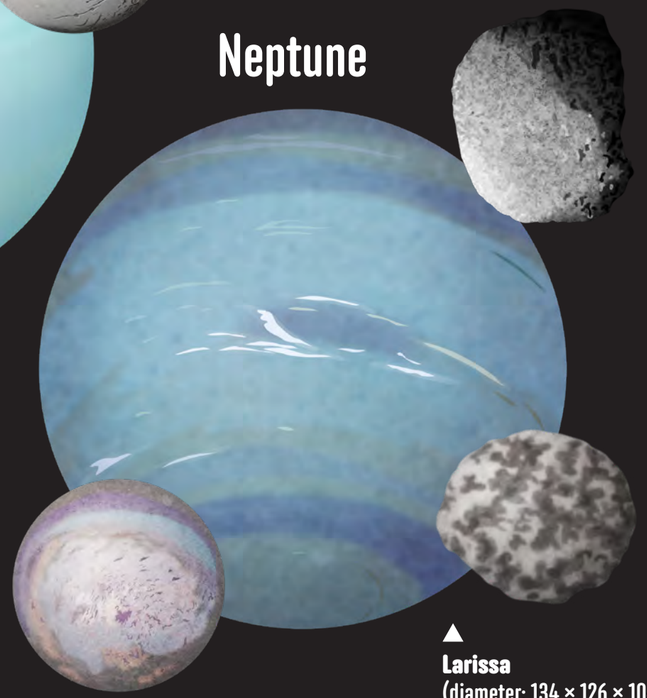
Umbriel (diameter: 726 miles)
Its surface contains a bright ring that might be frost deposits from an impact crater.

Triton (diameter: 1,680 miles)
An unusual moon with peculiar volcanoes.



Neptune

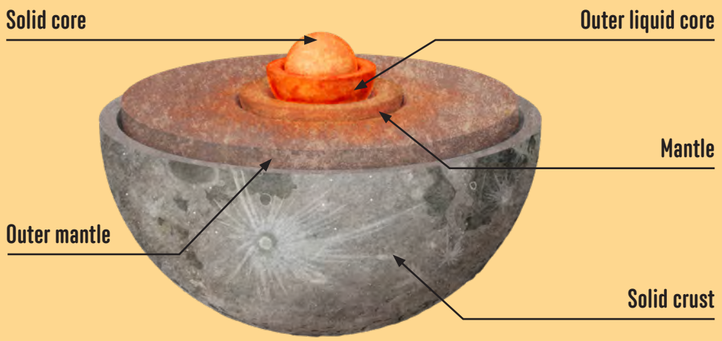
Larissa
(diameter: 134 × 126 × 104 miles)
A small, irregular moon.

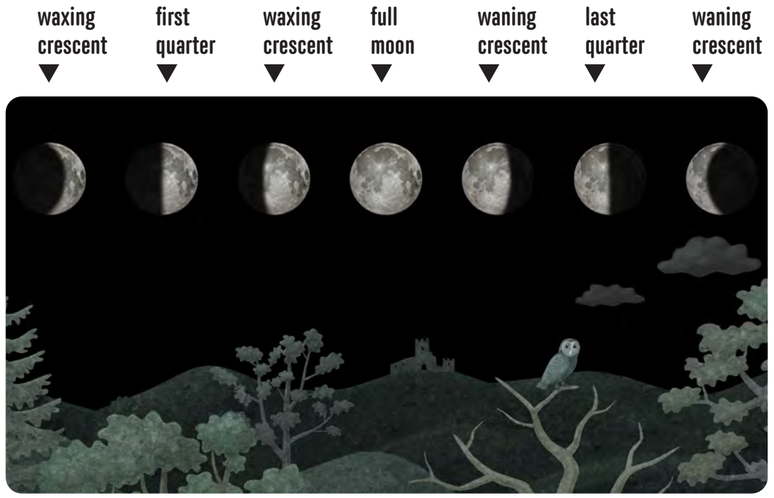


OUR CLOSEST NEIGHBOR

Inside the Moon

The Moon has a **solid core** surrounded by a **liquid outer core**, about 410 miles in diameter. Above this is the **outer mantle**, nearly 620 miles in diameter. This is surrounded by a **mantle** that is covered by a **solid crust** that is only a few miles thick.



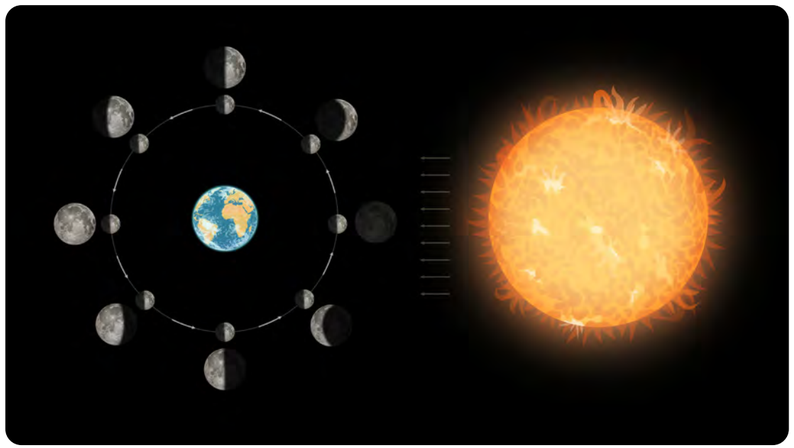


Lunar phases

The Moon in the sky is constantly changing its appearance. These are called the phases of the Moon. It starts with the **new moon**, which can't be seen because this is when its dark side is facing us. Then it moves on to the **waxing crescent**, the **first quarter**, and the **full moon**, which are visible in the night sky. After that, the **full moon** starts to shrink – or *wane* – becoming the **last quarter**, the **waning crescent**, and finally the **new moon** again.

The Moon orbiting Earth

When the Moon orbits around the Earth, it shows us its sunlit side. If the Moon is between the Sun and the Earth, we see its dark side. If Earth is between the Sun and the Moon, we see the near side of our cosmic neighbor, and the night sky is lit up with a full moon.

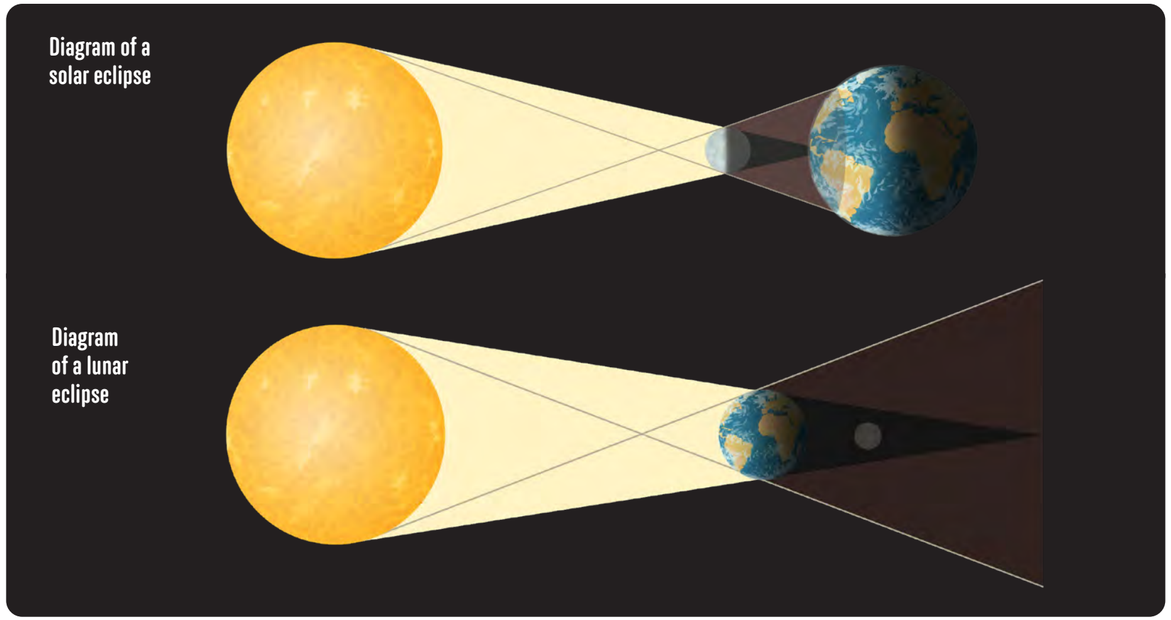


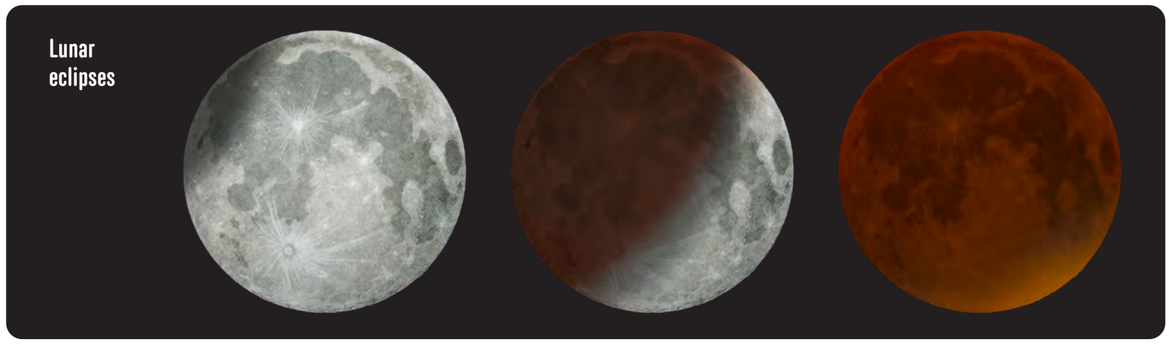
How solar eclipses happen

Because the Moon and Sun just so happen to take up the same amount of space in the Earth's sky, if the three bodies line up, they produce one of the most remarkable astronomical sights ever – the solar eclipse. If the Moon only "bites off" a piece of the Sun, we call it a partial solar eclipse.

Total solar eclipse

During a total solar eclipse, the daytime sky turns so dark that the brightest stars and planets become visible. The Sun is surrounded by a beautiful silver-blue aura known as the corona. A total solar eclipse can last up to 7 and a half minutes.



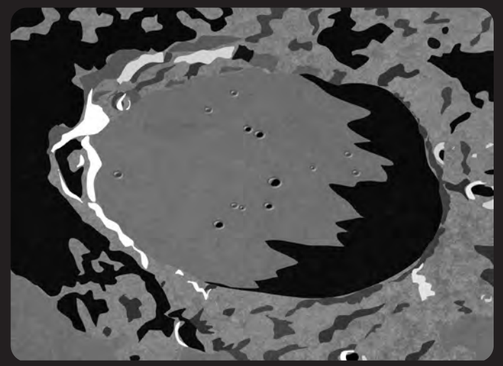


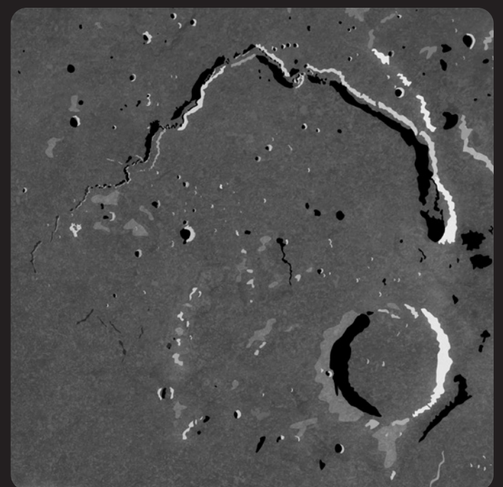
How lunar eclipses happen

Sometimes, you can see a beautiful sight in the sky – a lunar eclipse. That's what happens when the Earth lines up exactly between the Sun and the Moon. Earth's shadow covers the Moon and you can watch the Moon slowly disappear.

Lunar eclipse

When the Moon is only partly in Earth's shadow, this is called a partial lunar eclipse. But if Earth's shadow completely covers the Moon, a total lunar eclipse happens and the Moon turns dark and red.





Filled-in crater

The Plato crater is full of solidified lava.

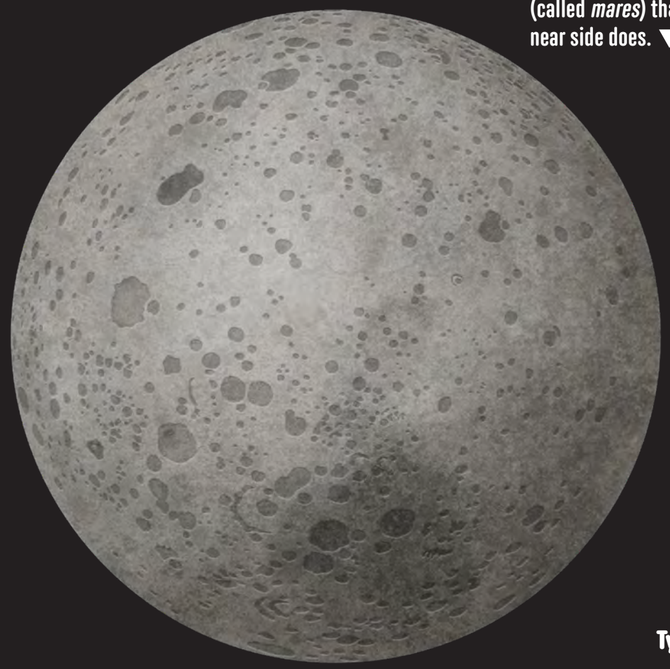
Schroter's Valley

A winding valley, once hollowed out by flowing lava.

A map of the Moon's near side.

The far side of the Moon

You can't see it from Earth. It has much fewer lunar large dark plains (called *mares*) than the near side does.



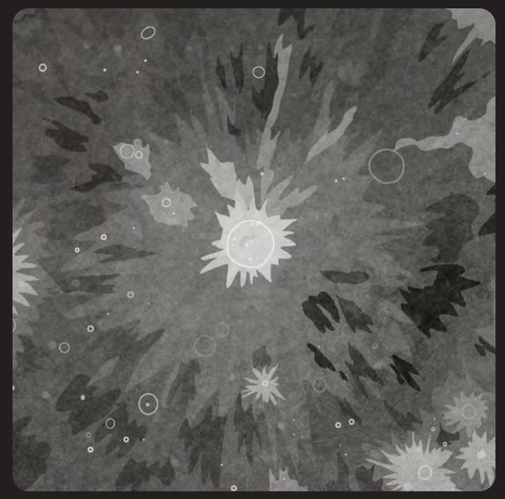
The radial Tycho

A crater named after the famous Danish astronomer. It's surrounded by bright lines spreading out like spokes from the center of a wheel.

Tycho Brahe

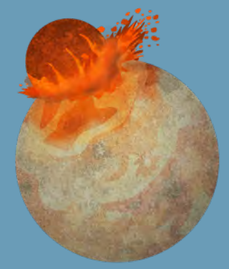
Copernicus crater

One of the youngest large craters on the Moon.

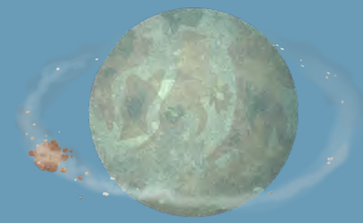


Origins of the Moon

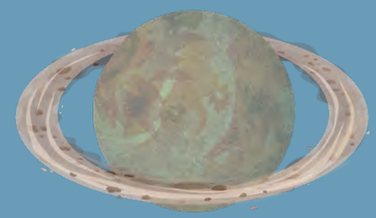
Approximately 4.4 billion years ago, a minor planet called Theia hit Earth.



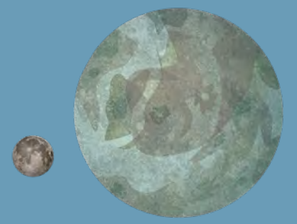
After this enormous collision, a large dust ring formed around Earth.



Various clusters of matter gradually formed in the ring of Earth's and Theia's debris.



The largest cluster of matter turned into our Moon which, along with Earth, attracted the remaining debris.



COSMIC TOTS

Meteors in the sky

Sometimes wrongly called shooting stars, meteors move quickly through the sky. Meteors are actually tiny pieces of cosmic dust that travel through Earth's atmosphere at high speeds. Thanks to air friction, they become very hot and create a brief light show called a **meteor**.

Meteorites

Every year, our planet is hit by tens of thousands of tons of cosmic material. Most of it burns up in the atmosphere, but some larger pieces make it to the ground. These rocks are called **meteorites**.

Fireballs

For a **meteoroid** to make it through Earth's atmosphere, it has to be large enough to not get completely burned up. If it passes through the atmosphere, it causes a spectacular light show called a **bolide** – or fireball. Some of these fireballs can be brighter than a full moon!

The largest known meteorite

The Hoba meteorite, located in the African country of Namibia, is the largest single meteorite ever found. It was discovered in 1920 by a farmer tilling the soil and was named **Hoba**, which means "gift" in the local language. This iron meteorite is 10 feet by 10 feet and weighs 66 tons. Scientists believe it landed on Earth less than 80,000 years ago.

The Chelyabinsk meteor

On the morning of February 15, 2013, a large meteorite collided into the Russian city of Chelyabinsk. The meteorite's flight through the atmosphere was recorded by many security cameras. Luckily, no one was injured, but the accompanying pressure wave caused extensive damage.

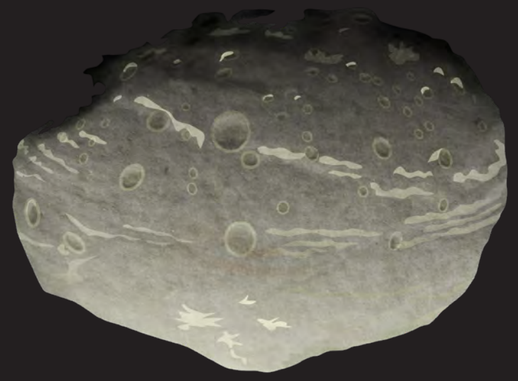
The Tunguska incident

On June 30, 1908, a powerful explosion rocked Siberia. The blast could be heard within a 620-mile radius. When scientists ventured into the inhospitable region, they found signs of a massive disaster. Trees within a 37-mile radius were completely knocked down. Scientists believe the disaster was caused by a 328-foot cosmic body that exploded high above ground, with the resulting pressure wave damaging forests far and wide.

Arizona crater

On our planet, the best-known depression left by a cosmic body can be found in the U.S. state of Arizona. A beautifully shaped crater with a diameter of nearly 4,000 feet and a depth of about 650 feet, it stands out clearly in the flat landscape. It was made roughly 50,000 years ago by a 63,000-ton iron meteorite.

Minor planet Vesta
Vesta is the second largest minor planet in the asteroid belt, located between Mars and Jupiter. Many meteorites come from Vesta.



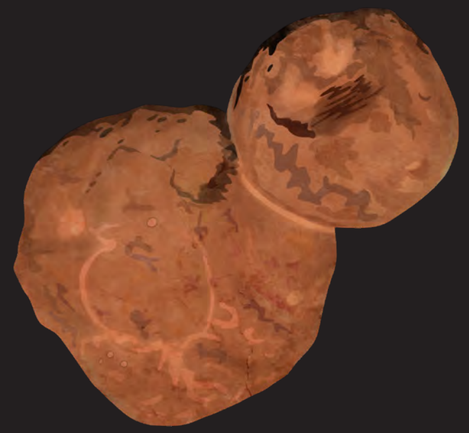
Meteoroid
A type of cosmic rock traveling through interplanetary space. When a meteoroid falls to Earth, it becomes what is called a meteorite.

Minor planet Eros
A minor, bone-shaped planet.

Ceres
The largest body between Mars and Jupiter. Because it is round, astronomers call it a dwarf planet.

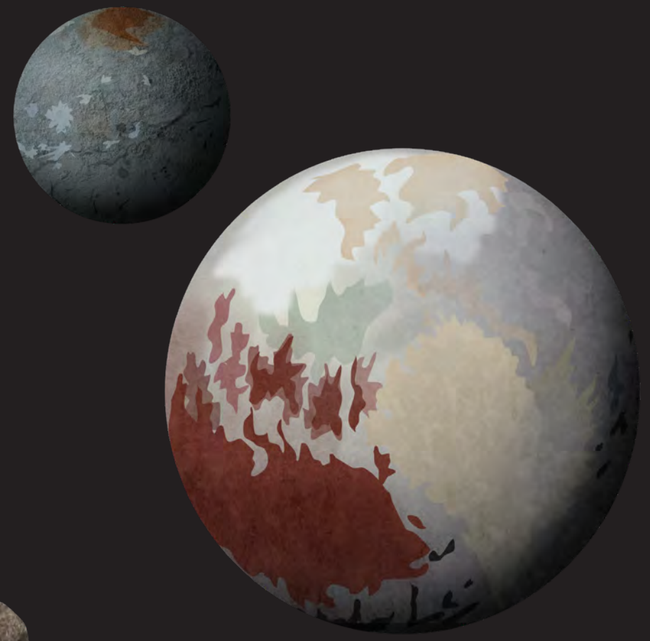
Minor planet Bennu
One of many minor planets, Bennu looks like a spinning wheel.

Arrokoth
Arrokoth is the farthest-away body ever visited by a cosmic probe.

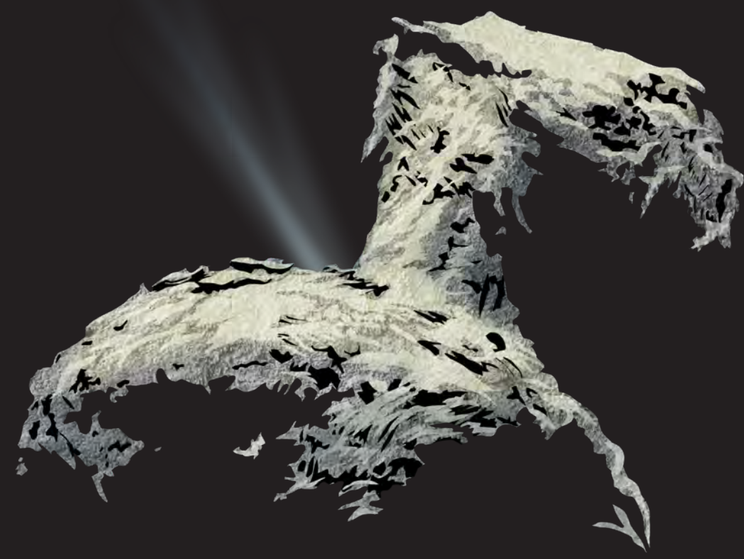


Oumuamua
A strange, noticeably elongated object that passed by Earth in 2017 and that might be a comet. Whatever it is, we know it didn't come from our solar system.

Pluto and Charon
The dwarf planet Pluto and its moon Charon.



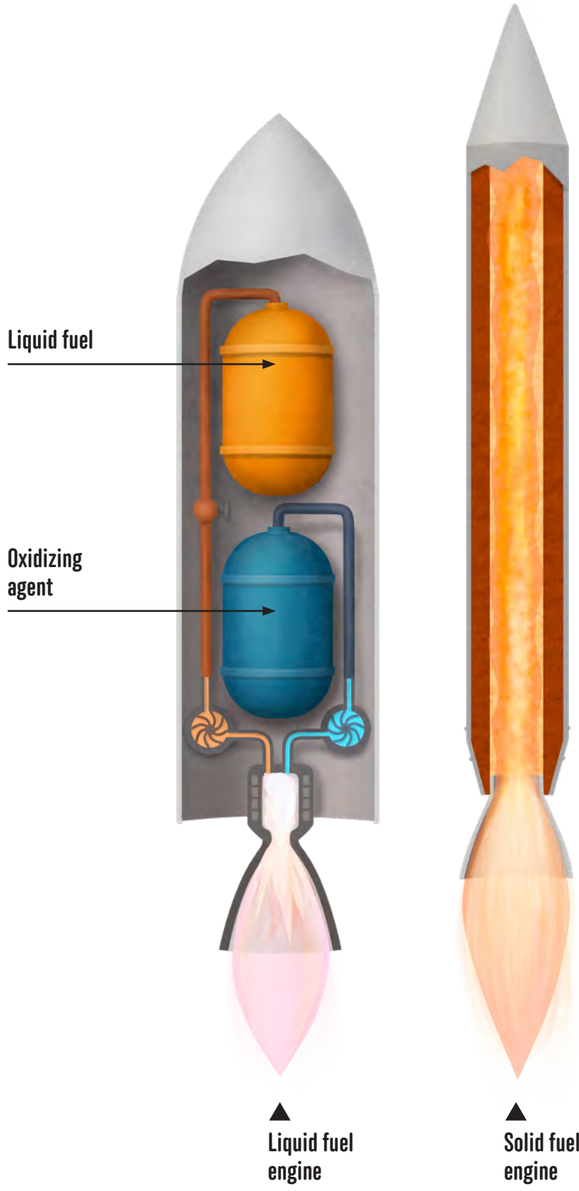
Churyumov–Gerasimenko comet
The core of the comet where the Philae probe landed in 2014.



SPACE FLIGHTS

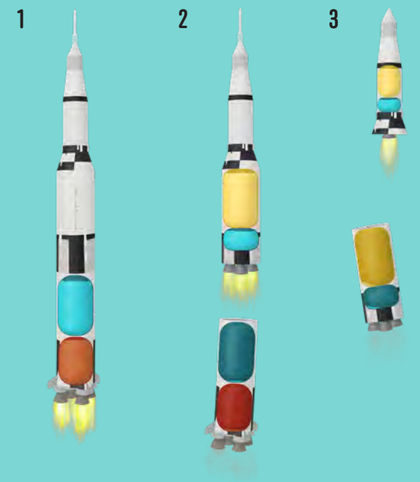
Liquid fuel engine

Rocket engines are all based on a simple rule: action and reaction. When they send gases out, the rocket moves in the opposite direction. The rocket's fuel shoots out from the bottom of the rocket, lifting it into the sky. But, as the rocket goes higher, there's less oxygen in the air, which can sometimes cause engine problems.



Saturn V launch vehicle

A huge spacecraft that took astronauts to the Moon. It had three main parts.



1. The first stage of the rocket burned for roughly 2.5 minutes and took the entire spacecraft 38 miles above the Earth.

2. After the first stage was disconnected, the second stage started, taking the shuttle 115 miles above the Earth.

3. After 6 minutes, the third stage lasted for 2.5 minutes, taking the spacecraft into Earth's orbit.

Solid fuel engine

Unlike liquid fuel engines, solid fuel engines don't need tanks. The engine is simply filled with a mixture, a fire is started, and the rocket takes off. Solid fuel engines are easy to fix and don't need to be pumped, like liquid fuel engines. The downside is that once the fire is lit, it can't be turned off. That's why they are mostly used in rocket boosters, like in space shuttles.

American shuttle

From 1981 to 2011, the Space Shuttle program transported materials and astronauts into Earth's orbit.

During lift-off, the shuttle's main engine and the two booster rockets ran at full power.

Roughly two minutes after lift-off, the two booster stages were dropped to parachute into the ocean.

After about 9 minutes of flight, the main tank was dropped and its remains burned up in the atmosphere.

Falcon Heavy

The strongest spacecraft of modern times, produced by the private company SpaceX, it first traveled into the outer space in February 2018.

The shuttle consists of three first stages and one second stage of the Falcon 9 launch vehicle.

After roughly 2.5 minutes of flying, two rocket boosters separate from the spacecraft and land on Earth.

Three minutes after take-off, the first stage's third booster separates and returns to Earth. The spacecraft is then powered by the second stage.

1957
The Soviet rocket Sputnik took the **Sputnik 1** satellite into orbit.

1958
The rocket Redstone took the first U.S. satellite, **Explorer 1**, into orbit.

1965–1975
The first type of the Soviet rocket **Soyuz** brought the eponymous spacecraft into orbit.

1960–1991
Vostok rockets were used to launch the **Vostok** spacecraft and Luna satellites.

1963–1976
Voskhod rockets were used to launch the **Voskhod** spacecraft and satellites orbiting Earth.

1957–1959
Vanguard rockets for releasing American satellites

1968–2020
Soviet carrier rocket **Kosmos-3M**

1965–1975
French carrier rocket **Diamant**

1965–1975
Saturn 1B rockets were mostly used to bring Apollo ships into low Earth orbit.

1967–1973
The huge **Saturn V** rockets took humans to the Moon.

1969–1972
The unsuccessful Soviet **N-1** rocket was meant to take humans to the Moon.

1989–2011
The American **Delta II** rockets took navigation satellites and probes to Mars.

Since 2002
Delta IV rockets take cargo into Earth's orbit.

Since 2004
Delta IV Heavy rockets are a more powerful version of the Delta IV rockets.

1962–1987
The American **Titan II** rocket launched the Gemini spacecraft and took satellites into Earth's orbit.

1966–1987
The American **Titan III B** rocket was used mostly to take military satellites into orbit.

1989–2005
Titan IV was the strongest version of the Titan series and took the Cassini probe to Saturn

1981–2011
The six shuttles of the **Space Shuttle** program: *Enterprise, Columbia, Challenger, Discovery, Atlantis*, and *Endeavour*.

1988
The unmanned Soviet shuttle **Buran** took only one test flight.

1985–2017
The Zenit family were Ukrainian rockets (originally Soviet). **Zenit 2** was the first one.

1977–2009
The Soviet launch vehicle **Tsyklon-3** took satellites into low Earth orbit.

1966
The **Atlas SLV-3B** was used only during the release of the OAO astronomical satellite.

1980–1978
The American **Atlas-Agena** rockets were used for sending cosmic probes to the Moon and Mars.

1991–1998
American carrier rocket **Atlas II**

1992–2004
American carrier rocket **Atlas III**

2002–2022
Atlas V is the fastest solid fuel rocket in history.

2000–2021
American solid fuel rocket **Minotaur 1**

2010–2020
American **Minotaur 4** rocket

1979–1986
European **Ariane 1** rocket

1986–1989
European **Ariane 2** rocket

Since 1996
European **Ariane 5** rocket

Since 1993
Indian **PSLV** carrier rocket

Since 2001
Indian **GSLV** carrier rocket

Since 2001
Japanese **H-IIA** carrier rocket

1975–1982
Japanese **N-I** carrier rockets

1981–1987
The Japanese **N-II** rockets replaced the older N-I model.

Since 1998
Israeli carrier rocket **Shavit**

Since 2012
Light European **Vega** rocket

Since 1965
Soviet **Proton** carrier rockets

Since 2013
American **Antares** carrier rockets

2008–2009
Falcon 1 is the first successful rocket by SpaceX.

2010–2013
The first version of **Falcon 9** was designated v 1.0.

2013–2016
Falcon 9 v 1.1 is the second version of Falcon 9.

Since 1992
Chinese **Long March 2D** rocket

Since 1999
Chinese **Long March 2F** rocket

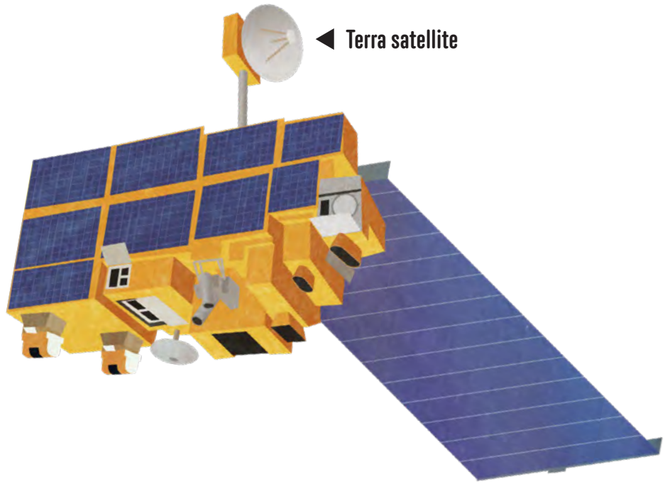
Since 2007
Chinese **Long March 3B/E** rocket

Since 1999
Chinese **Long March 4B** rocket

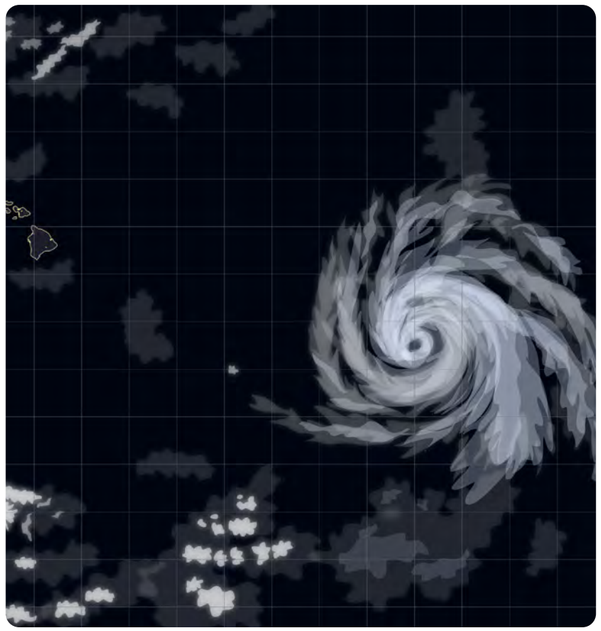
COSMIC SPIES

Earth under supervision ▶

Right this moment, dozens of satellites are circling above you at altitudes ranging from several hundred to several thousand miles away! They help with TV broadcasting and they monitor the weather, send data from one continent to another, look out for spreading forest fires, and watch the spread of dust from large volcanic eruptions. These satellites even save lives by helping search for lost ships in the ocean and providing connection to remote places. Earth is being watched over by these satellites as we speak.



◀ Terra satellite



Weather forecast ▶

A fleet of satellites from different countries is constantly monitoring the movements of clouds. Supercomputers process a large amount of satellite data to figure out what's happening in the atmosphere. However, developments in the weather can also depend on other circumstances that we can't yet accurately predict.

Timely warnings

These allow people living in the affected area to be warned days before strong winds and catastrophic floods arrive.

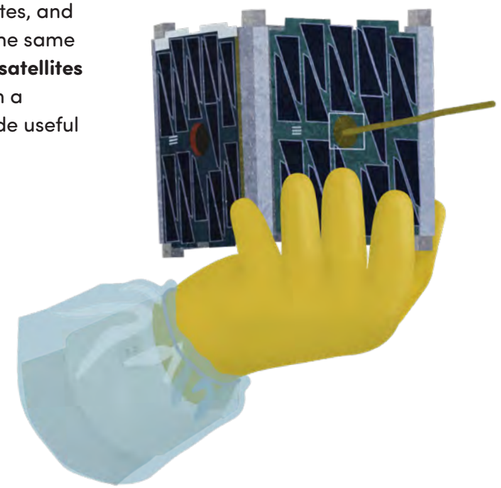
◀ Satellite image showing an approaching hurricane.

Meteosat satellite ▶

A satellite in your pocket

These days, it's not just government and scientific institutions but also private companies that send satellites into outer space. They are much less expensive than large satellites, and many can be launched at the same time. These so-called **nanosatellites** are so small they could fit in a shoebox, yet they still provide useful measurements from orbit.

Nanosatellite ▼

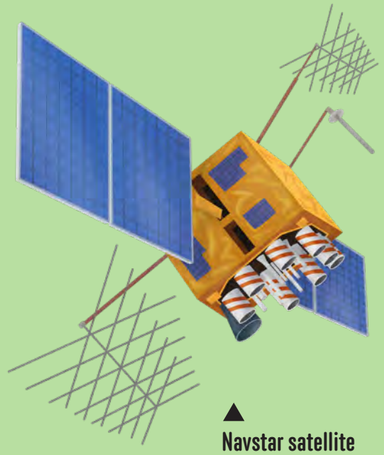


Sputnik 2 ▶

Laika, the first animal cosmonaut

Animal cosmonauts

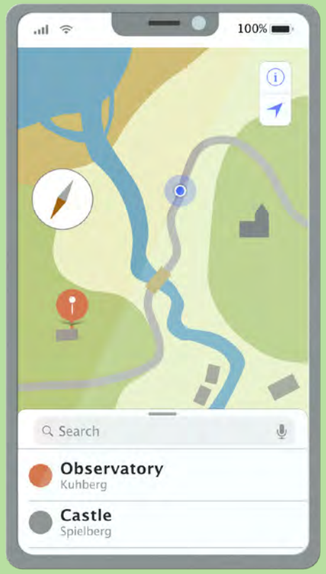
The first animal cosmonauts were a dog and a chimp . . .
In November 1957, a stray dog named Laika traveled into outer space on board the Soviet satellite Sputnik 2. Four years later, a chimpanzee named Ham went into orbit on board the U.S. ship Mercury-Redstone 2.



▲ Navstar satellite

Satellite navigation

Satellite navigation was initially designed for military use, but now almost everyone takes advantage of it – from taxi drivers to tourists to people delivering food. The first system available for regular use was Navstar GPS, which has been helping people accurately pinpoint their location anywhere on Earth since 2000.



▲ GPS application

1. Sputnik 1 (launched: 1957)
On October 4, 1957, the Soviet Union released the very first artificial satellite in history.

2. Explorer 1 (launched: 1958)
The first artificial satellite released by the United States.

3. Tiros 1 (launched: 1960)
An American satellite that became the first successful meteorological satellite.

4. Telstar 1 (launched: 1962)
A satellite that arranged the first ever live broadcast between the U.S. and Europe.

5. Gambit 3 (1966–1984)
A series of dozens of American reconnaissance satellites.

6. Iridium (launched: 1997)
Satellites that ensure phone connection from any place on Earth.

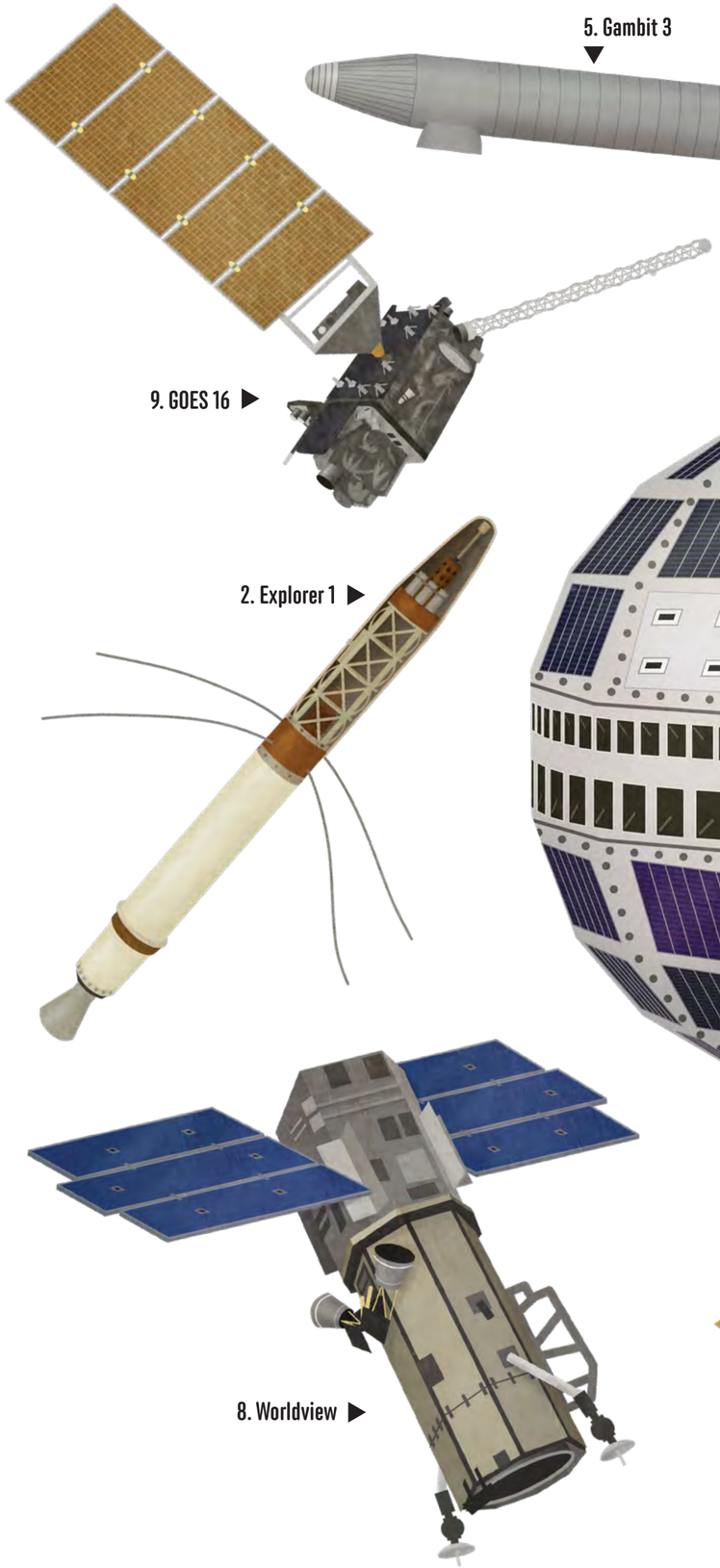
7. GRACE (launched: 2002)
A research satellite that measures the Earth's gravitational field.

8. WorldView 2 (launched: 2009)
A commercial satellite used for imaging Earth.

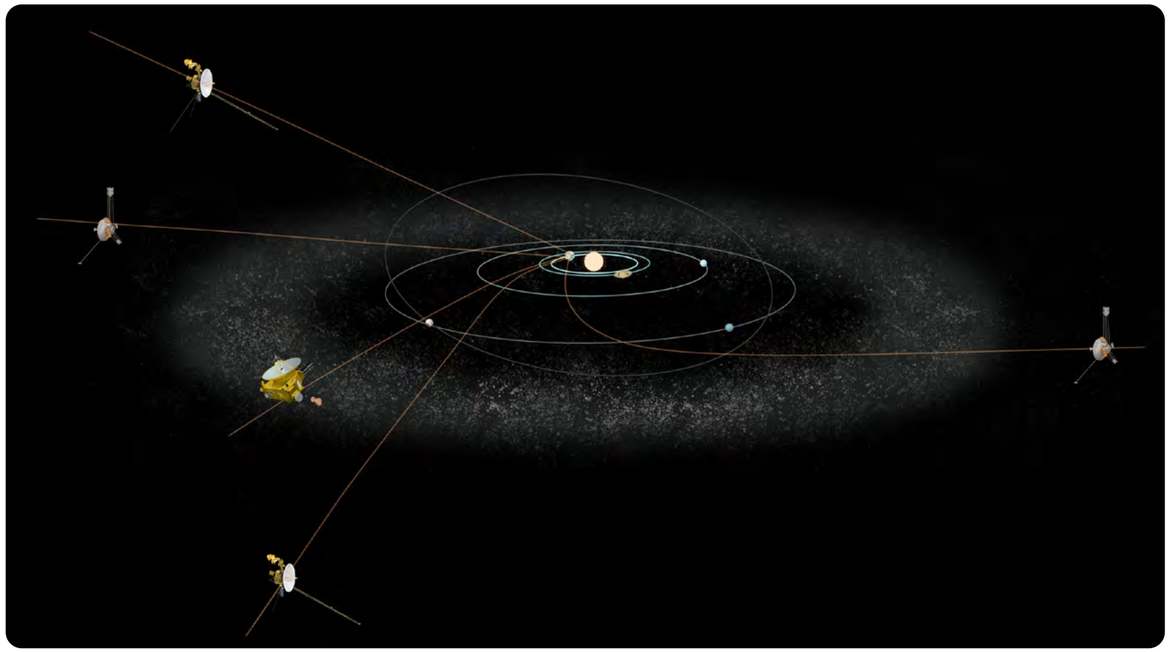
9. GOES 16 (launched: 2016)
A meteorological satellite that monitors the Western hemisphere from an altitude of 22,000 miles.

10. Sentinel 6 (launched: 2020)
A satellite that makes accurate measurements of the surfaces of seas and oceans.

Note: The sizes of the individual satellites here are not shown in relation to one another.



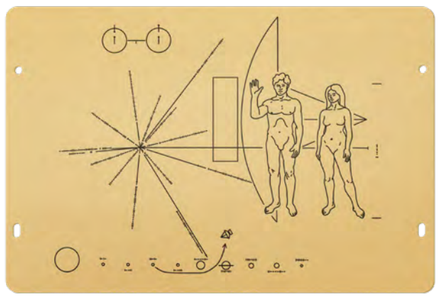
EXPLORING FOREIGN WORLDS



▲

Patient voyagers

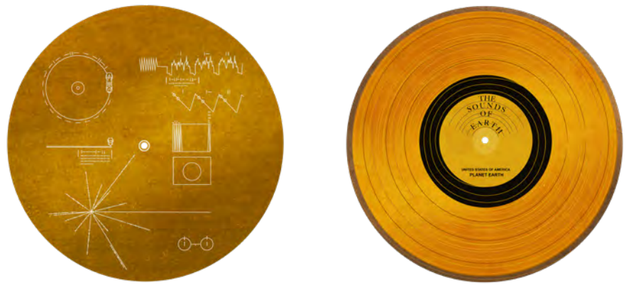
People have sent many cosmic probes into space to explore our solar system. Pioneer 10 lost connection with Earth when it was a full 7.5 billion miles away from us. Its twin, Pioneer 11, fell silent beyond Pluto. The two Voyager probes, which were launched in 1977 and left our solar system in recent years, are more tireless wanderers. Both of them are separated from us by more 12.4 billion miles. The New Horizons probe, which paid a visit to Pluto, is now over 5 billion miles away from Earth.



▲

Postcard from space

In 1972 and 1973, Pioneer 10 and 11 were launched on a mission to explore other planets. They were equipped with plates carrying a message for any alien civilizations they might encounter, including our location in the universe.



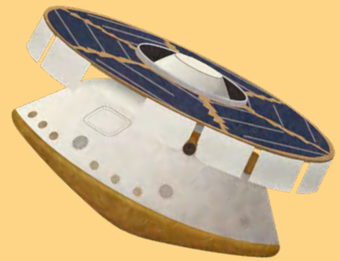
▲

Golden records

The two Voyager probes both carry golden records from 1977 containing Earth's sounds, music, and greetings in different languages. In case the probes are ever found by an extraterrestrial civilization, these records are there to share our planet's human culture.

Landing on Mars

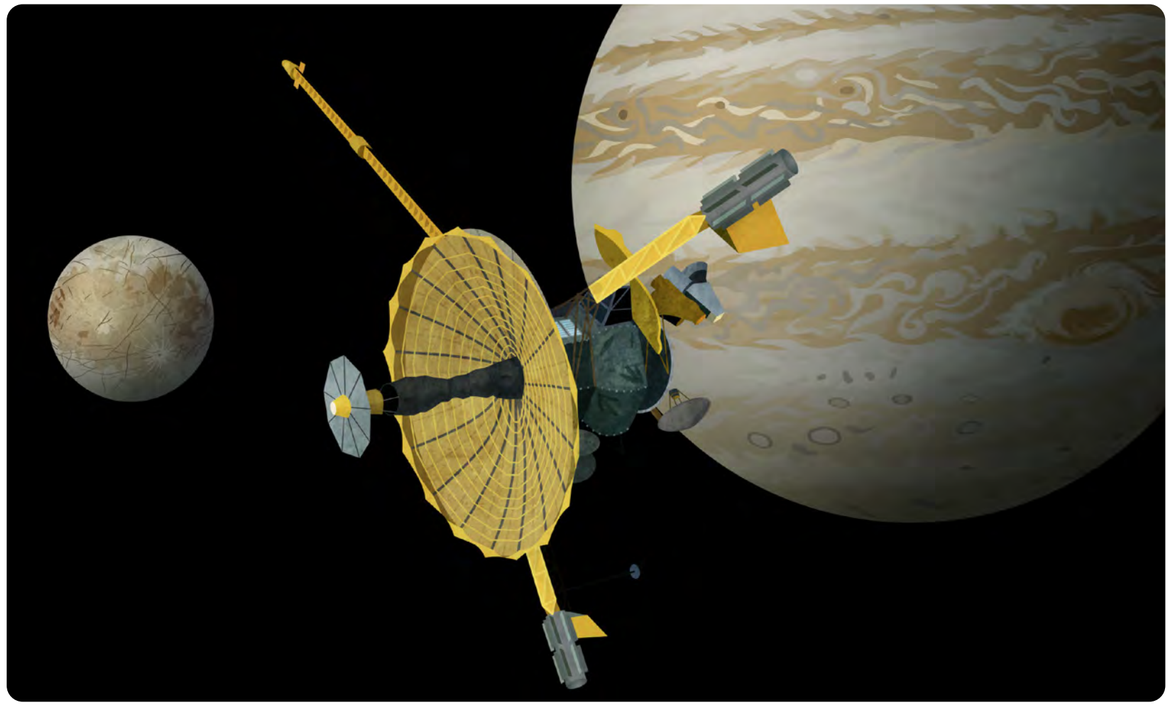
Do you know which part of traveling to Mars is the riskiest for cosmic rovers? It's when they enter Mars's atmosphere and land. This is called the "**7 minutes of terror**" because that's how long it takes. Everything has to go right during this critical stage or else the rover will crash onto the surface of Mars.



1 – A probe with a heat shield that protects it against enormous heat is entering Mars's atmosphere, where it's met with a temperature of over 3,600 degrees Fahrenheit!

2 – Roughly 6 miles above the surface of Mars, a huge parachute opens, breaking the rover's fall.

3 – The rover is too heavy for a parachute to slow its descent, so rocket engines are used to guarantee a soft landing on the planet's surface.



▲ **Galileo (launched: 1989)** a probe for exploring Jupiter and its moons.

1. Pioneer 10 and 11 (1972 and 1973)
The first planetary probes meant for exploring Jupiter and Saturn.

2. Viking 1 and 2 (launched: 1975)
A couple of probes that successfully landed on the surface of Mars in 1976.

3. Venera 9 (launched: 1975)
The first probe that managed to land on Venus.

4. Voyager 1 and 2 (launched: 1977)
Two amazing probes that explored all of the large planets in our system before continuing into interstellar space.

5. Sojourner (launched: 1996)
The first robotic rover on Mars.

6. Spirit and Opportunity (launched: 2003)
A couple of robotic rovers that explored the surface of Mars for a few years.

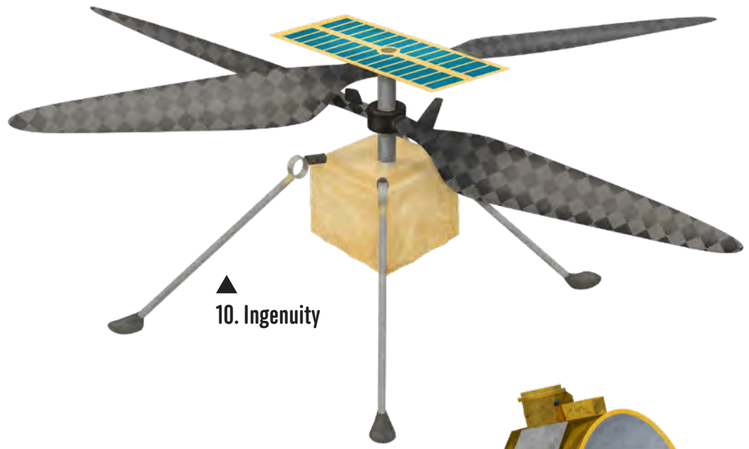
7. New Horizons (launched: 2006)
So far, the only probe to visit the dwarf planet Pluto.

8. Curiosity (launched: 2011)
In 2011, the Curiosity rover landed on Mars.

9. Perseverance (launched: 2020)
A mobile scientific laboratory that landed in the Jezero crater on Mars in 2021.

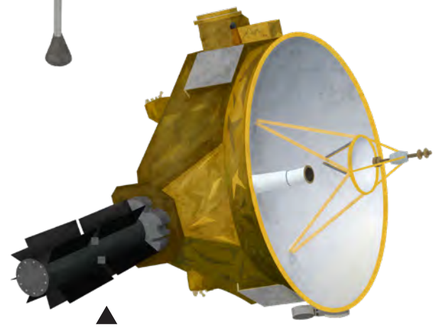
10. Mini-helicopter Ingenuity
The Perseverance laboratory also includes a small reconnaissance helicopter.

Note: The sizes of the individual probes here are not shown in relation to one another.

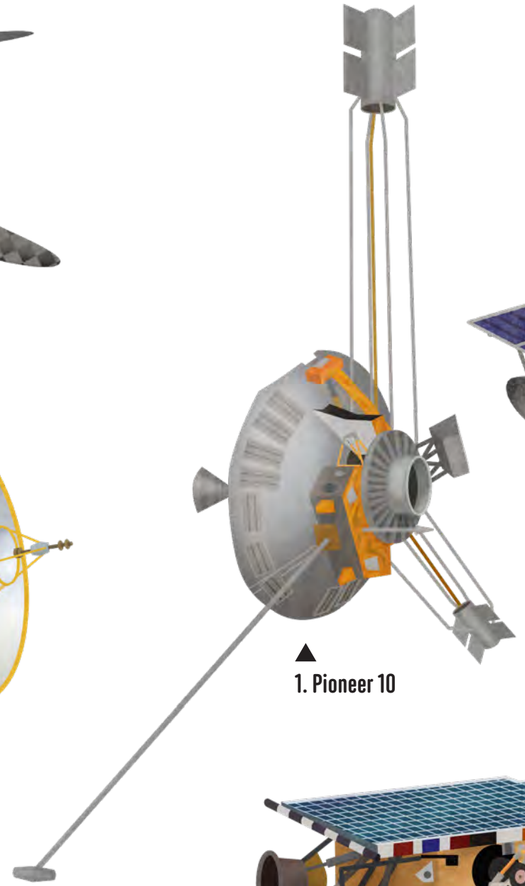


10. Ingenuity

4. Voyager 1



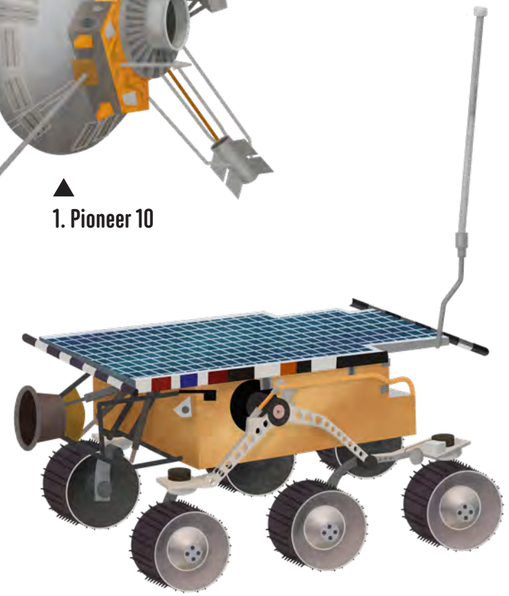
7. New Horizons



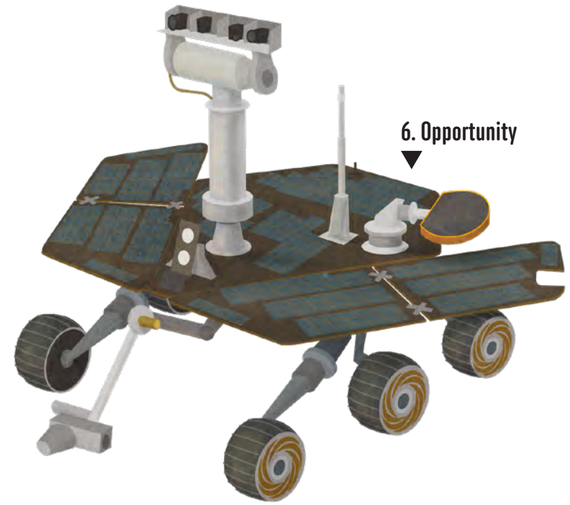
1. Pioneer 10

2. Viking 1

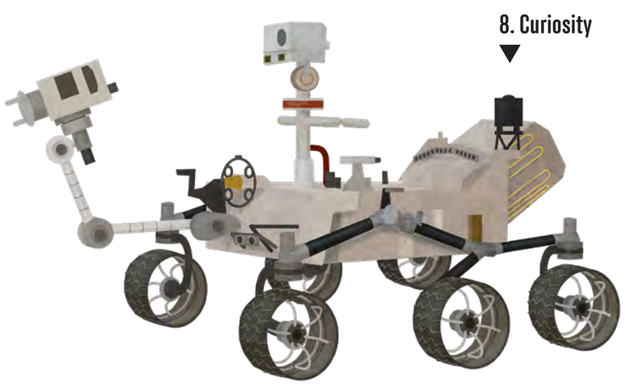
3. Venera 9



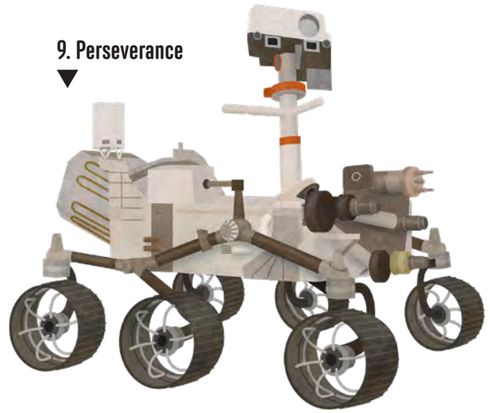
5. Sojourner



6. Opportunity



8. Curiosity



9. Perseverance

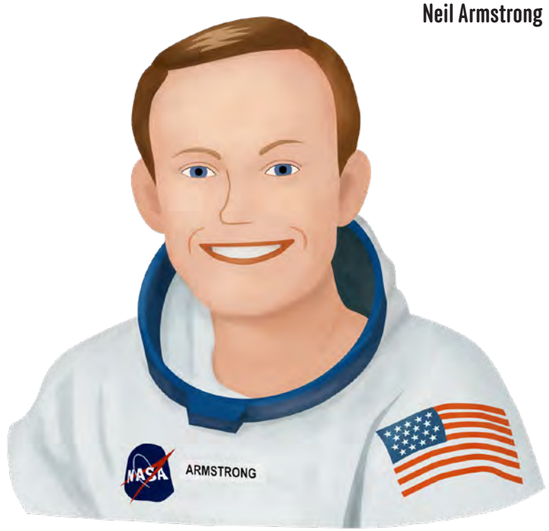
SPACE ADVENTURERS

Yuri Gagarin

The first person in outer space

The first person to ever travel into outer space was Soviet cosmonaut Yuri Gagarin. On April 12, 1961, he lifted off from the Baikonur Cosmodrome, and about an hour and forty minutes later, safely landed back on Earth in a Vostok space capsule as part of the Vostok spaceflight program. He became the first person in history to see our planet from outer space and describe its beauty.

Neil Armstrong



The first person on the Moon

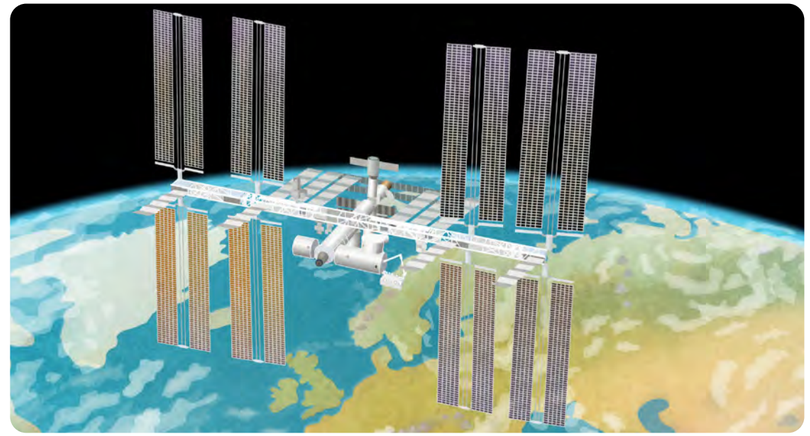
In July 1969, the crew of the American space mission Apollo 11 landed in the Moon's Mare Tranquillitatis region. Two astronauts were on board: Buzz Aldrin and Neil Armstrong. Armgstron was the first to leave the lunar module and set foot on the Moon. After Apollo 11's successful landing, there were five other missions, which transported 10 astronauts in total. The last mission was in December 1972, which was also the last time, to date, that a person has been on the Moon.

How fast do you need to fly to get to outer space?

1. If a rocket is moving at a slow speed, it falls back to Earth.
2. If a rocket goes faster than 17,670 miles per hour, it starts to orbit the Earth.
3. Once it reaches a speed of 40,320 miles per hour, it can escape the Earth's gravitational pull and head off to the Moon, for example.

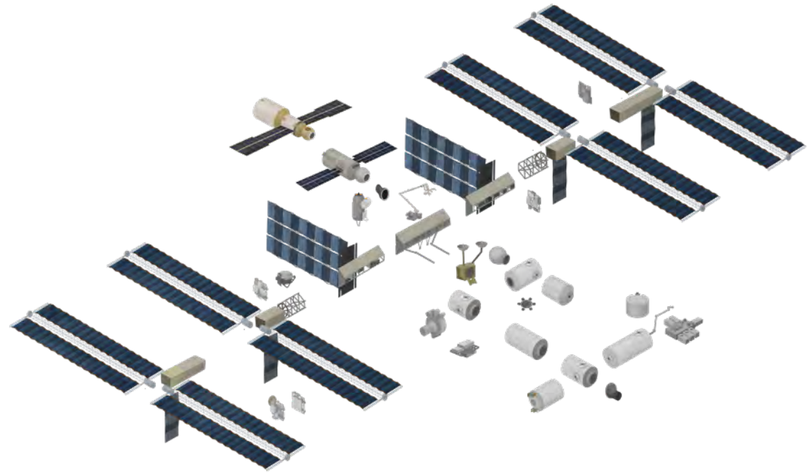
Space Stations

These are large cosmic stations orbiting Earth. Astronauts travel here in small ships that park at the station and then are used to travel back. The stations are sort of like "summer camps" where astronauts go to fulfill scientific tasks.



International Space Station (ISS)

The International Space Station (ISS) is the largest cosmic station in the world, involving many countries and five space agencies. It is like a set of building blocks, measuring over 328 feet long, which started being constructed in 1998. The ISS is located about 248 miles above Earth, and has a crew of 7 astronauts that rotates every couple of months.



Russian spacecraft Soyuz for transporting astronauts to the ISS

Russian cargo ship Progress for regular supplies of materials and food

Cygnus automated cargo ship

European ATV cargo ship

Japanese HTV cargo ship

Manned Dragon spacecraft of the private company SpaceX

Equipment for spacewalking astronauts

◀ Gilded visor to protect astronauts against the sun's rays

▲ All of the important spacesuit functions are controlled via a module attached to the belly.

▲ This part of the spacesuit allows the arms to move.

Astronaut ▼

▲ Secondary oxygen pack for longer stays in oxygen-less environments

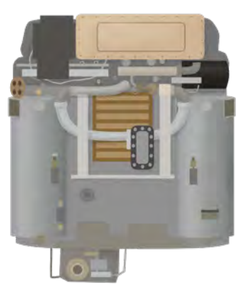
▲ Protective outer gloves

▲ Drinking device with a tube leading to the astronaut's head

▲ Pants leg with many insulation layers

▲ Shoes with insoles adapted to feet size

▲ Spacesuit's upper torso



▲ This pack provides the astronaut with oxygen and absorbs the carbon dioxide they breathe out.

▲ Suspension bag for sleeping in a cosmic station.

▲ Bathrooms in space stations are very complex devices.

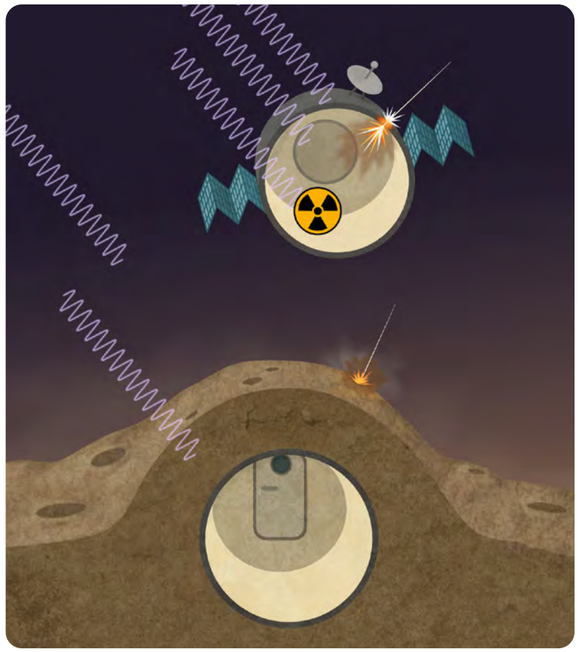
▲ Spacesuits include special temperature regulating systems.

▲ Precise electric "screwdriver" that can be handled with thick gloves

◀ Spacewalking astronauts are tethered to the ship with a rope.

▲ Food for astronauts

COLONIZING THE UNIVERSE



Cosmic rain

On Earth, our atmosphere shields us from cosmic radiation and meteorites. But on the Moon and other planets, we won't have that protection. That's why, in the future, we will need to build strong bases. Cosmic rocks don't slow down in environments without an atmosphere and can hit us at speeds of up to tens of thousands of miles an hour. At that speed, even a ping-pong ball can penetrate solid armor.

Extra-terrestrial garden

Getting fresh vegetables to the Moon or even to Mars would be very expensive. That's why building extraterrestrial bases would mean that the people living there would have to grow certain kinds of fruits and vegetables themselves – likely in enclosed structures controlled by machines, with artificial lighting. What will a Martian tomato taste like?

Dangerous dust

The surface of the Moon is very dusty. But this dust isn't like the kind you clean out of your closet! Moon dust particles, called **regolith**, aren't smoothed over by the wind or water. That's why they're as sharp as a thistle. They can get stuck in your skin, cause breathing problems if you breathe them in, and get stuck in moving parts. Future missions will have to figure out how to handle the problems that regolith can cause.

Other worlds

Astronomers have discovered more than 5,000 planets orbiting stars in other solar systems. These worlds, known as **exoplanets**, are mostly gas giants similar to Jupiter and Neptune. However, a couple hundred of them are small and rocky like Earth.

Dangerous aliens

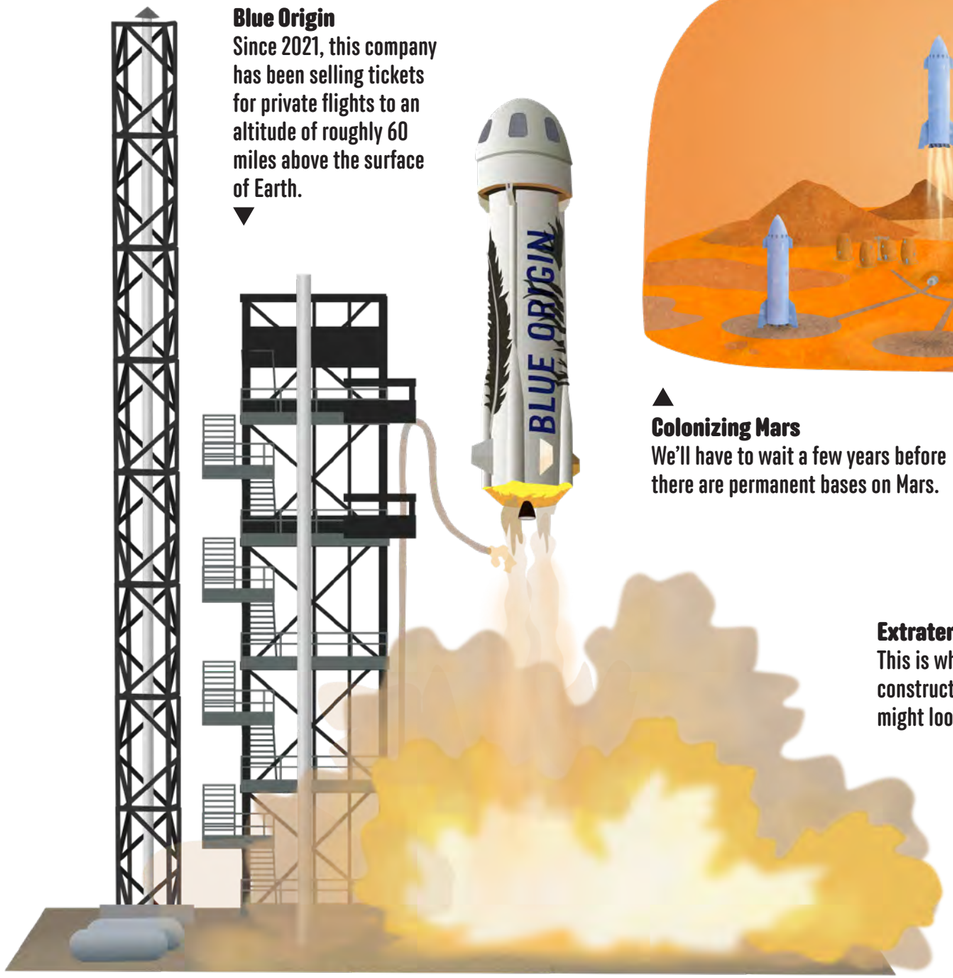
Exploring foreign worlds could bring astronauts into contact with unknown microbes. If the astronauts got infected and returned to Earth, it could be dangerous for all of us. That's why the first missions to the Moon required the Apollo crews to stay in quarantine for three weeks upon returning.

Water bear

Microscopic supermen

The tardigrade – or **water bear** – is the toughest creature on Earth. It's smaller than the period at the end of this sentence, but it can survive intense radiation, stay frozen for 30 years, and live in dry deserts, icy glaciers, the ocean depths, and even inside volcanoes.

Blue Origin
Since 2021, this company has been selling tickets for private flights to an altitude of roughly 60 miles above the surface of Earth.
▼



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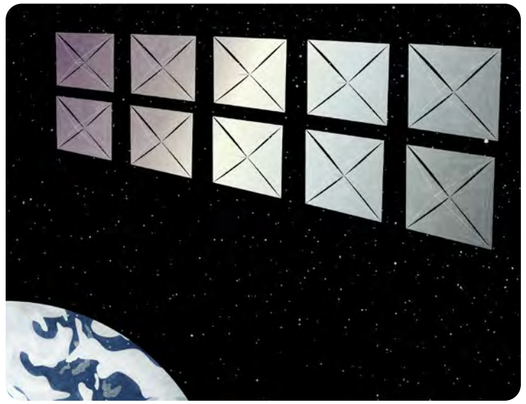
Colonizing Mars
We'll have to wait a few years before there are permanent bases on Mars.



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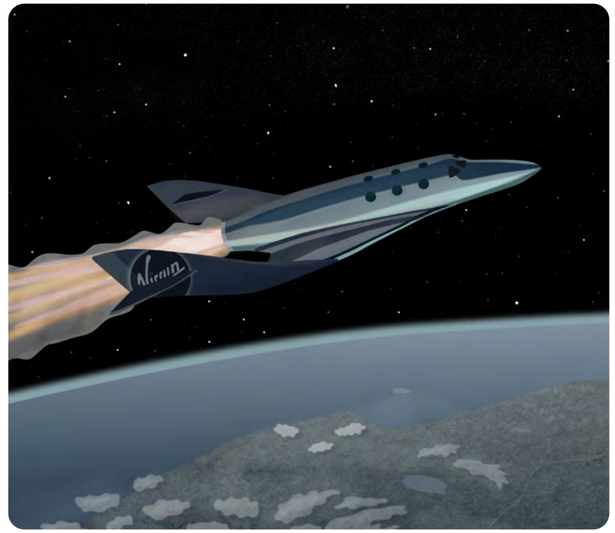
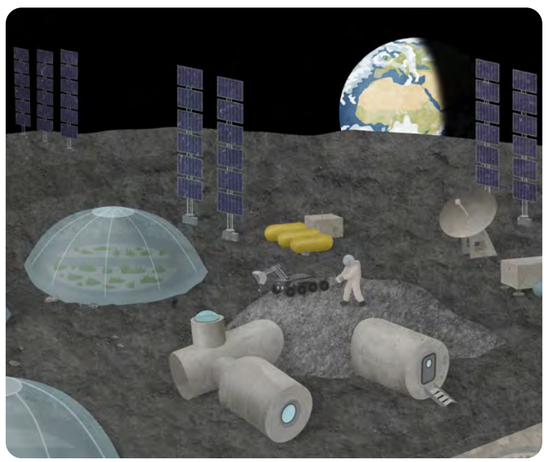
Cosmic sailboats
Interstellar space could be explored with probes propelled by the solar wind.



▲
Virgin Galactic
A private company currently offering to take you into outer space for a couple of minutes – and for nearly half a million dollars!

Extraterrestrial construction ▶
This is what the robotic construction of Martian bases might look like.

▲
Star power
Orbital stations and bases on planets might run on solar power.



▲
Bases on lunar poles
There might be enough solar power and water ice to live on the Moon.

▲
Sky hotels
In the future, there might be hotels up in Earth's orbit, housing tourists interested in experiencing outer space.

▲
Towards distant planets
After we go to Mars, even more remote destinations await us – such as the moons orbiting Jupiter.

Pavel Gabzdyl is a planetary scientist who works at the Brno Observatory and Planetarium in the Czech Republic. He has written many popular science articles and several books on objects in our solar system. In 2004, he realized his dream of holding a moon rock – his exploration of this topic resulted in his being awarded a master's degree in Geology. A planet, Gabzdyl (43971), was named after him in 2007. In 2013, he received the Littera Astronomica Award from the Czech Astronomical Society for his work in popularizing science.

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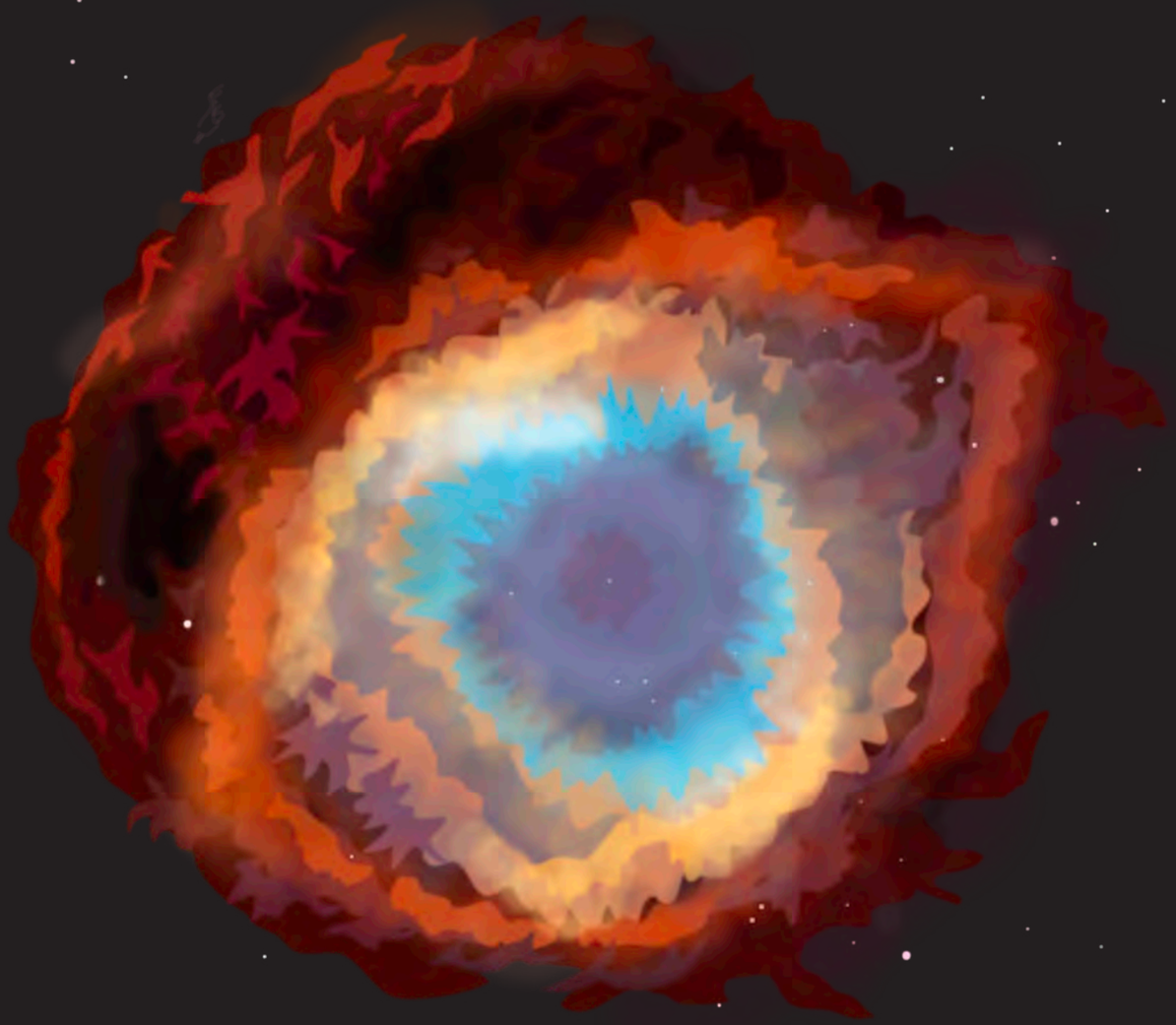
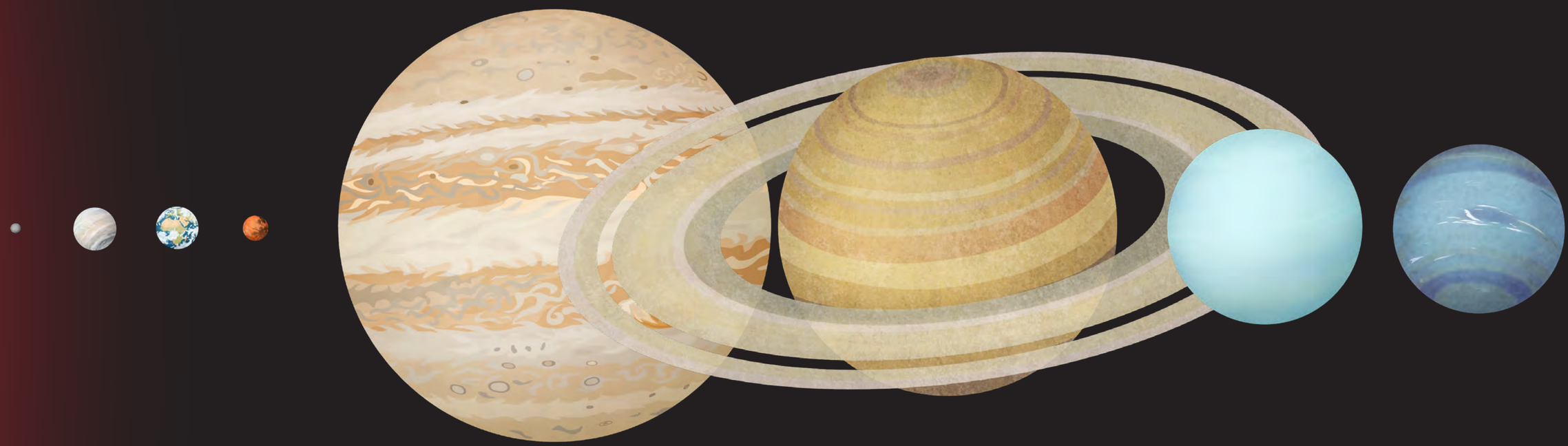
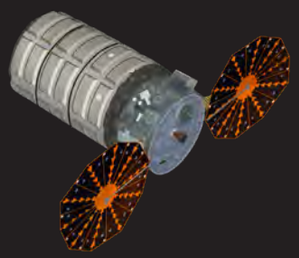


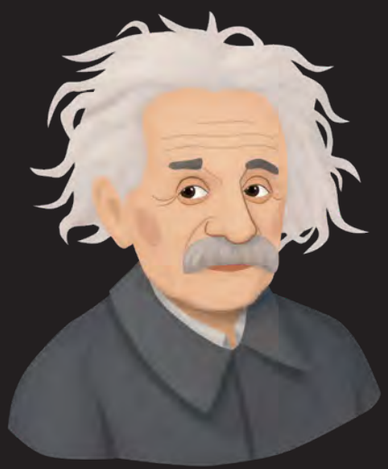
SOLAR SYSTEM

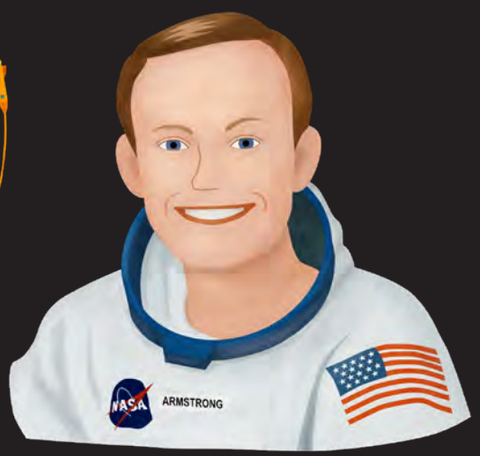
Note: While the sizes of the planets in relation to the Sun are proportional, the distances are not.



Sun / Mercury / Venus / Earth / Mars / Jupiter / Saturn / Uranus / Neptune







SPACEMANIA

Encyclopedia of the Universe

The world of stars, planets, galaxies, celestial bodies, and space flights is as endlessly fascinating as the universe itself. From the very first moment when humans looked up at the night sky, it was clear that humankind would never stop being excited and astonished by outer space; that people would study it for as long as it remained shrouded in mystery, full of unexplained things happening. While a single book can't ever hope to contain everything there is to know about the universe, it can at least give you a list of the most interesting things. And that's what ***Spacemania*** is all about. Be it the origin of the universe, the celestial bodies that can be found in its depths, or its conquest by humans – this book will introduce you to everything important and worthy of exploring about space.

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