DIAGRAM OF OUR UNIVERSE 2018

Earth's orbit is about 100 trillion times the size of a thumbtack hole.

What is the Universe?

The Universe is the breadth of time and space that includes all physical entities. Humans, the landscapes that we see, the plants and animals that live here - all of this is a part of the Universe. The stars that shine in the night sky, the Milky Way, which spreads its pale light among the stars, and galaxies so far away that they can only be seen with a huge telescope - all these things are part of the Universe as well. The Universe encompasses all the things that we know, and everything beyond.

Planck spacecraft

This diagram is based on the assumption of the "Lemaître Universe", which is a uniform, isotropic Universe with no curvature. Calculations are based on the latest observational results from the Planck spacecraft.

In our Universe, elements were born

Stars were born from the elements

Humans were born from the stars and then Science was born

Early Chordates — Fishes — Amphibians — Early Mammals — Early Primates — Early Prosimians — Early Simians — Apes — Apeman — Humans

What is science?

Science is a method for understanding all of the objects and phenomena that comprise the Universe. When we notice something strange, we naturally ask "Why?" This is the first step in science. Scientific methodology means investigating the phenomena that interest us through experiments and observation, so that we can gain a deeper understanding. Through this process, we find new ways of seeing and new ways of thinking. This is scientific discovery. Science is one way of knowing the Universe around us.

Earth is about 10 billion times the size of a thumbtack hole.

How to use this diagram

Experience the Universe using four rules

This diagram illustrates the Universe based on the latest research and observations, with humans at the center. The vertical represents the passage of time, from the age of humans back to the birth of the Universe. The horizontal represents the breadth of space that is the Universe. From its overall inverted cone shape, we can see that the Universe has been expanding constantly ever since it first came into existence. This diagram is a guide that will take you on a journey through time and space. Keep these four rules in mind as you uncover the secrets of the Universe with your own eyes.

Rule 1 Looking into the distant Universe means looking into the past

The strange thing is that when we look at the Universe from the Earth, what we see is actually the Universe as it was in the distant past. For example, when we look at the Sun, we are actually seeing what it looked like eight minutes ago. When we look at Pleiades (Star cluster M45), what we are actually seeing is what this star cluster looked like about 400 years ago. Why does this happen? We see stars and galaxies because the light they emit travels to where we are, but they are so far away that it takes time for light to even reach us. By the time that light gets here, the stars that emitted that light have changed.

Light reaches the Earth (We can see what the star looked like 10 billion years ago)

The Earth

The Earth is created

4.6 billion years ago

8 billion years ago

10 billion years ago

12 billion years ago

13.8 billion years ago

Light spreads out in all directions

Light is emitted by celestial bodies

Celestial bodies are created

The birth of the Universe

Rule 2 There is an "observable" Universe and much larger volume that lies behind our ability to observe it

The "Current Universe" spreads out on all sides of the human being pictured at the center of the diagram, but we are unable to see what this Universe really looks like. Remember Rule 1: What we see is the Universe as it was in the past. If we compare this diagram to the celestial bodies that we can see with the naked eye or through telescopes, we find a teardrop shape like the one shown in the center of the diagram. This is the only part of the Universe that we can see, and even these celestial bodies are images from a different era, thousands, millions, or even billions of years ago.

The Earth
A celestial body
Light emitted from that celestial body
Today

Time
Our current location
Today's Universe
the top surface of the inverted cone
Space
The Universe expands to become "the Universe as we see it today"
Light emitted by celestial bodies spreads out and expands
"The Universe as we see it today" (the surface of the teardrop shape)

Rule 3 The expanding Universe forms a teardrop shape

Light from the furthest point in the observable Universe has traveled for 13.8 billion years. If the Universe had been static, the light could have traveled only 4.2 million years to reach our current location. During that time, however, the Universe has continued to expand, so the light path has grown increasingly longer from the time when the journey began, and the starting point is much further away at this moment. The teardrop shape is the trajectory of the light from the observable Universe. By the time the light reaches us, that starting point is estimated to be as far as 45 billion light years away (the edge of the top surface of the inverted cone). Since the Universe is expanding, any light emitted from the edge now will never reach the Earth.

Rule 4 The Universe becomes visible through the "Eyes of Science"

The observable Universe (the teardrop-shaped image at the center of the diagram) is only a drop in the bucket compared to the vast expanse of the actual Universe. Through the "Eyes of Science", however, we have learned a great deal using clues from the observable Universe. How was the observable Universe created (the bottom of the inverted cone)? How has it expanded (the outer surface of the cone)? And does a Universe exist beyond the outer limits of this cone? This diagram contains the results of many such scientific discoveries. The Universe is waiting for you to unravel its mysteries.

DIAGRAM OF OUR UNIVERSE 2018

The slope of this yellow line represents the speed of light on the Earth.

Looking for life on the planets of our Solar System

Does life exist somewhere in the Universe, aside from on the planet Earth? First, let's look at the possibilities in our own Solar System. Our Solar System comprises several celestial bodies of various sizes and environments.

Our Solar System includes: the Sun, eight planets, dwarf planets, small Solar System bodies (including asteroids, comets, trans-Neptunian objects and other small bodies), **and satellites.**

The Sun: One of the more than 100 billion light-emitting stars in the Milky Way galaxy

Mercury Venus Earth Mars Ceres Jupiter Saturn Uranus Neptune

Terrestrial planets — Planets composed mainly of rock

Asteroid belt (Ceres is classified as a dwarf planet)

Jupiter-type or "Jovian" planets — Giant planets composed mainly of hydrogen and helium

Trans-Neptunian objects — Celestial bodies composed of ice, found outside of Neptune's orbit

Pluto

Plutoids (included in dwarf planets)

Pluto Haumea Makemake Eris

Developments in space exploration technologies have enabled new scientific research aimed at seeking out life on other planets. We can now send probes directly to other planets in our Solar System to look for traces of life. Among the main targets for these probes are Mars, where liquid was thought to exist on the planet's surface, and Europa (one of Jupiter's moons), where an ocean is believed to lie hidden under a thick layer of ice. There is little likelihood of finding intelligent life or advanced life forms there, but one day, we may discover microorganisms on these celestial bodies similar to those found on Earth.

Water ice found on Mars (left), vaporized after a few days (right).

Europa

Does life exist outside of our Solar System?

Discovery of exoplanet worlds

Does life exist in the vast expanses of the Universe outside of our Solar System? In 1995, for the first time in history, astronomers discovered a planet around a distant star. Since then, astronomers have discovered more than 3,500 planets outside of our Solar System, using a variety of clues; for example, minute variations in the movement of stars resulting from the revolution of planets around the stars, or slight changes in the brightness of stars when planets pass in front of them. Planets outside of the Solar System are called "exoplanets".

Hunting for "Another Earth"

Based on observations by astronomers up to now, we have learned that there are many diverse planetary systems outside of our own. Recently, in addition to large, heavy "Jovian" planets, astronomers have discovered planets that are similar to Earth in both size and mass. Furthermore, a number of the planets discovered could potentially sustain large bodies of liquid water on the surface, given that they maintain an appropriate distance from their host stars, as is the case for Earth. The range of orbits where liquid water can exist is named the Habitable Zone, and dozens of planets, including some Earth-sized planets, have been discovered in this zone.

Thirty Meter Telescope (TMT) will be built by international cooperation

Searching for life on exoplanets

Celestial bodies outside of our Solar System are so far away that even if we found a planet that could be called another Earth, we would not be able to send a probe to explore it directly. Therefore we must use other methods to determine whether those planets could sustain life; for example, by observing the planet's surface environment or atmosphere using space telescopes or extremely large telescopes on Earth to confirm whether water exists there in liquid form, or by looking for traces of substances such as oxygen, ozone, and methane, which living organisms could potentially create (referred to as "biosignatures"). Future research will help to clarify whether analogs to terrestrial planets and terrestrial life exist elsewhere in the Universe.

Planet LHS 1140 b — 0.1 au (1 au is approximately 1 earth-sun distance) — Star — Habitable zone

Habitable zone (green) of the LHS 1140 system and the orbit of the exoplanet LHS 1140 b

HOW DID OUR UNIVERSE COME INTO EXISTENCE?

This vast Universe we can observe was once so small that it could not be seen. Modern science is closing in on the secrets of the Universe, and is gradually gaining an understanding of the astounding origin behind the formation of the Universe itself. Let's look back at the history of the Universe, starting from the moment of its formation.

The presumed current state of the Universe - Countless stars shining in the darkness

This is the state of the Universe, as brought to light by recent observations. About 70% of the Universe is "dark energy", a mysterious form of energy that accelerates the expansion of the Universe. About 30% is an unidentified substance called "dark matter", and about 5% is made up of normal matter*. The Universe has a diverse layered structure comprising galaxies with tens or hundreds of billions of stars, galaxy clusters that contain hundreds or even thousands of galaxies, and a large, mesh-like structure of galaxies that are spread out across hundreds of millions of light years.

* 'Normal matter' is the basic components that comprise all substances in the world around us. All things, from animals to stars in the night sky, including our own bodies, are made up of combinations of normal matter.

Galaxy cluster Abell 2744

Spiral galaxy M 81

Normal matter 5%
Dark matter 26%
Dark energy 69%

Composition of the Universe, as determined by the Planck spacecraft and other sources

The mesh of the Universe - Dark matter and large-scale structures

Why are galaxies distributed in the form of a mesh? The answer is "dark matter", a substance that remains unexplained, and which cannot be directly observed. It is believed that in volumes containing dark matter, gravity caused even more dark matter to gather and create "large-scale structures" in the form of a three-dimensional mesh. Normal matter then collapsed onto the sites where large amounts of dark matter resided, eventually forming galaxies embedded in these large-scale structures.

Start of calculations — Approx. 4.5 billion years later — Approx. 13 billion years later

Dark matter is distributed uniformly

Fluctuations have formed in the distribution of dark matter

Large-scale structures have formed

These are simulated images of the evolution of large-scale structures in the Universe. The blue gaseous substance represents dark matter. In reality, dark matter is invisible.

The first star brings light to the Universe - The birth of stars and galaxies

We know from observations that galaxies already existed in the Universe about 13.4 billion years ago, but we don't know exactly when the first stars were born. We believe that the first stars had dozens of times more mass than our Sun. A variety of elements were created inside these giant stars. These elements were scattered by supernova explosions and they became the seeds for new generations of stars.

The first star in the Universe (simulated image)

The oldest galaxy yet discovered: GN-z11 (13.4 billion years ago)

Atoms appear, and the fog of the Universe lifts - Electrons combine with atomic nuclei

Up until that time, the Universe was superheated, with huge volumes of "electrons*1" flying back and forth. These electrons crashed into photons, preventing light from moving in a straight line, and making the entire Universe opaque, as though in the middle of a fog. When the temperature of the Universe dropped to around 3,000 K, however, electrons bonded with atomic nuclei to form "atoms", which no longer impeded the movement of light. In this way, the Universe became much clearer*2 like a fog lifting. This event is known as recombination. Atoms with similar properties, referred to as elements, would eventually become the materials from which the first stars formed.

*1: When substances are broken down into their most basic ingredients, the smallest component, which cannot be broken down any further, is referred to as an "elementary particle". Electrons and photons are examples of these elementary particles.

*2: The light that was dispersed when this happened can still be observed by humans today, as "cosmic microwave background radiation".

H Hydrogen atom — He Helium atom — recombination

Proton — Hydrogen atomic nucleus — Electron — Electron — Helium atomic nucleus — Neutron — Gluon

Particle: Photon, Electron, Up quark, Down quark, Antiparticle: Positron, Anti-up quark, Anti-down quark

Types of elemental particles

Matter particles	Quark	Up quark, down quark, etc.
	Lepton	Electron, neutrino, etc.
Particles that transmit power	Photon	A medium for electromagnetic power
	Weak boson	A medium for the weak force that acts between elemental particles
	Gluon	A medium for the strong force that connects quarks
	Higgs particle	Particles that accompany activity in the Higgs field

Formation of the Higgs field

The beginning of the Big Bang

Inflation

The three minutes in which everything was created - The starting point in the creation of matter

Only about three minutes after the birth of the Universe: that's the time it took to create all of the matter that exists in the Universe around us. During these three minutes, the superheated Universe cooled off as it expanded at an incredible rate. Quarks, another type of elementary particle and a building block of matter, gathered to form protons and neutrons. Then, these protons and neutrons came together to form the "atomic nuclei" of hydrogen and helium, the lightest of all the elements. About 92% of all the atomic nuclei created at this time were hydrogen, and the remaining 8% were helium. Now, let's take a closer look at the Universe before matter existed.

The Universe as a superheated fireball - The "Big Bang"

In times past, the Universe was a superheated, super-condensed fireball, heated by an incalculable amount of energy*1. This is what is now referred to as the Big Bang. During this event, huge volumes of elementary particles, including photons, were created. These photons flew about at the speed of light, but about 1 trillionth of a second after the beginning of the Big Bang, a "Higgs field" was formed. Interactions with this field impeded the movement of specific elementary particles, slowing them down below the speed of light. With this hindered movement, the elementary particles gained inertial mass*2. There are two types of elementary particles: particles, and antiparticles. When these two substances collide, they cease to exist, becoming weightless particles, photons. Because there were about 1 billion times more particles than antiparticles, the former were left behind*3. These left-over particles are believed to have become the substance of the Universe as we know it today.

*1 The temperature at this time was a billion billion billion degrees (1×10^{32} K).

*2 There are two types of mass: inertial mass, which resists movement, and gravitational mass, which causes universal gravitation. These two types of mass are exactly the same, but the reason for this is still unknown.

*3 Antiparticles are still being created and disappearing today.

Where did the Big Bang occur?

The entire Universe as we see it today was created through the Big Bang. In other words, the Big Bang occurred in every location in the Universe. If you go back far enough in time, every place in the Universe was where the spot the Big Bang took place.

The beginning of space and time - "Inflation": The rapid expansion of the Universe

Immediately before the incredible heat of the Big Bang, the Universe cooled down to absolute zero as a result of unimaginable exponential expansion of space - the period called "inflation". The Universe is believed to have been inflated at a fantastic pace by "vacuum energy", which is similar to the dark energy that accelerates the current expansion of the Universe but is much larger, on a scale of 10^{100} times. When the Universe cooled down to absolute zero, the nature of the vacuum changed, and the space was filled with hot plasma. So, what happened before inflation...?

The path of expansion

This inverted cone shape represents the path of expansion taken by "the Universe as we see it today", from the birth of the Universe to the present. The objects on the outermost edge are furthest away from us, and are currently traveling at more than three times the speed of light.

The accelerating expansion of the Universe

After the initial period of inflation, the speed of expansion gradually decreased (decelerating expansion), but an increase in the speed of expansion has been observed, from about 6 billion years ago to the present (accelerating expansion).

Accelerating expansion — Decelerating expansion

Is there anything outside of the inverted cone?

According to numerous theories, including the "Inflating Universe" theory, the Universe is far more expansive than the scope illustrated in this diagram. We can estimate what lies outside of these lines, but it would be impossible to confirm these speculations objectively.

Our Galaxy — Our Solar System — The Earth — Subaru Telescope — ALMA

Dawn of multi-messenger astronomy

Now we can observe the Universe through not only electromagnetic waves but also neutrinos, gravitational waves, and cosmic rays. "Multi-messenger" astronomy, which combines observations of electromagnetic waves and other signals, leads to a further understanding of the Universe.

KAGRA — IceCube — Super-Kamiokande

Cosmic event horizon

Since the Universe is expanding, any electromagnetic waves, neutrinos, and gravitational waves from outside of this surface never reach to the location of the Earth.

Space, moving away at the speed of light

The light blue line illustrates the space that is moving away from the Earth at exactly the speed of light, as a result of the Universe's expansion. Space that is further away is moving away from the Earth even faster than the speed of light. Because the expansion of the Universe is the expansion of space itself, even if the rate of change in the distance between a given point in space and another point exceeds the speed of light, it does not contradict the "principle of the constancy of the speed of light".

Speed of light — Galaxy cluster Abell 1827

"The Universe as we see it today"

Using space as the x-axis and time as the y-axis, all celestial bodies currently visible to us can be arranged on the surface of this teardrop. The light emitted by these celestial bodies reaches the Earth after traveling along the surface of this teardrop.

Galaxy cluster Abell 1689 — Galaxy cluster CL 2244-02 — Galaxy cluster SE 295 — Supernova 1997ds — Galaxy cluster XX 1059.2+43.9 — Early galaxy — Galaxy cluster — Supernova 1997ff — Early star — Galaxy cluster — Galaxy — Quasar — Cosmic Microwave Background (CMB): observed by the Planck spacecraft. This image shows the oldest light in the Universe, when the Universe was 380,000 years old.

Center of the diagram

This diagram, shaped like an inverted cone, is a graphical representation of the expansion of the Universe. At the center is the Earth, where we stand as we observe the Universe. We are thus at the center of the diagram. But where is the center of the Universe? In fact, astronomers believe that the Universe is homogeneous and isotropic, that is, in "the Universe as we see it today", there is no unique location that could be called the "center of the Universe".

Time — Space — The Earth — Today — The Sun — Galaxy cluster Abell 1827 — Galaxy cluster Abell 1689 — Galaxy cluster CL 2244-02 — Galaxy cluster SE 295 — Supernova 1997ds — Galaxy cluster XX 1059.2+43.9 — Early galaxy — Galaxy — Early star — Galaxy — Quasar — Cosmic Microwave Background (CMB)

About 13.8 billion years

30 billion light years — 40 billion light years — 45 billion light years

About 45 billion light years: the current radius of "The Universe as we see it today"

- You're reading the diagram of Our Universe.
- The birth of Science
- Human years ago: The birth of human beings
- 66 million years ago: The extinction of the dinosaurs
- 252 million years ago: The biggest extinction in the history of the Earth
- 541 million years ago: The Cambrian explosion (dramatic action of life forms)
- 700 million years ago: Snowball Earth
- 1 billion years ago: Appearance of multicelled organisms
- 1.9 billion years ago: Oxygen
- 2.1 billion years ago: The first supercontinent
- 2.3 billion years ago: Snowball Earth
- 2.7 billion years ago: Development of photosynthetic organisms (cyanobacteria)
- 3 billion years ago: The formation of geomagnetism
- 3.5 billion years ago: Fossils of prokaryotic organisms (bacteria)
- 4 billion years ago: Traces of primordial life
- 4.6 billion years ago: Formation of the oceans
- 13.8 billion years ago: Formation of our Solar System, and the Earth

We can observe galaxy cluster JKCS 041 through the light emitted at the top of the teardrop. We can estimate this by using different possibilities, but we have no way of knowing whether this galaxy cluster still exists, because on a universal scale, we are unable to observe the "present".

Collisions of celestial bodies

The type of violent collision that caused the extinction of the dinosaurs occurred on numerous occasions throughout the Earth's history.

"Snowball Earth"

There are believed to have been two periods at least in history during which the entire surface of the Earth was frozen over.

Development of geomagnetism

The Earth's magnetic field became stronger, blocking radiation from the Sun and from outer space, and creating an environment on Earth that was capable of supporting life.

Creation of the Earth and formation of the Moon

The Earth was born 4.6 billion years ago, and within one hundred million years a collision between the Earth and a celestial body the size of Mars gave birth to the Moon.

The life of a star

Stars are created in clouds of gas and dust orbiting within galaxies. The lifetime of a star, and its final form, differ depending on the star's mass. Many of the materials that make up the stars ultimately return to the Universe, becoming the materials for the next generation of stars.

Nebula — Protostar — Gas and dust — Main sequence star — Brown dwarf — Red giant — Red supergiant — Wolf-Rayet star — Supernova explosion — Neutron star — Black hole — Planetary nebula — White dwarf

The colors of these symbols correspond to the colors of segments in the table of human materials.

The heavier the star, the less time each process takes.

High-mass — Low-mass

The path of a celestial body and light

The white dotted lines represent the paths taken by galaxy cluster JKCS 041 as it moves away from us due to the expansion of the Universe. The yellow dotted lines represent light emitted at this time by galaxy cluster JKCS 041, the light reaching us only billions of years after the Big Bang.

Celestial bodies moving away faster than the speed of light

Space on the widest part of the teardrop was traveling away at exactly the speed of light at the moment when it emitted that light. The surface of the teardrop lower than the widest point (farther) in the past represents space moving away faster than the speed of light. We are also observing light emitted by celestial bodies that are moving away faster than the speed of light, when the light left, which has yet to reach us, was emitted.

The Big Bang — 42 million light years — recombination - Approx. 370,000 years — The beginning of the Big Bang — Expanding at below the speed of light — 10s

The radius of "the Universe as we see it today" was somewhere between a few centimeters and a few meters at the moment of the beginning of the Big Bang.

Inflation

WHAT IS THE MATERIALS' ORIGIN OF HUMANS?

The human body, which could be compared to a small "Universe", comprises materials called elements. Modern science has determined that these elements originated in the stars and were scattered through space eons ago. Let's go back in time to unravel the mysteries of human beings and the Universe.

Element — DNA — Nerve cell

The human body is made up of cells. Within these cells, human genomes, which are the blueprints for the human body, are drawn with DNA. These cells and DNA are in turn made up of elements.

Table of human materials

Black letters indicate the main elements comprising the human body. Colors show the origin of the elements.

big bang fusion
dying low mass stars
exploding white dwarfs
exploding massive stars
merging neutron stars
cosmic ray fission
short-lived or unstable elements

Life was formed from a variety of elements - The birth and evolution of life on the Earth

Currently, many life forms, including human beings, thrive on the Earth. More than 4 billion years ago, the first life appeared on the Earth. It is still not clearly understood how the first life was formed*, but various elements in the water are believed to have combined and undergone chemical reactions, gradually forming complex organic molecules, and eventually giving birth to the first life on Earth. But if the Earth gave birth to life, then how did the Universe bring the Earth into being?

10 μm — A fossil of a living organism from about 3.5 billion years ago

Membranes formed in the water, which contained organic substances, and self-replicating organisms appeared.

There are several possible locations for the origin of life on Earth including oceans, hot springs and so on.

The stage is set for the formation of life - The formation of our Solar System, and the Earth

The Earth and the other planets of our Solar System were formed about 4.6 billion years ago. Gas and dust floating in interstellar space gradually condensed into a disk and formed the Sun at the center. Around the same time, material further out in this disk collapsed to form the Earth and other planets*. But where did this material come from? It was the remnants of stars that have long since disappeared.

*In galaxies throughout the Universe, there are innumerable places where gas and dust particles finer than grains of sand coalesce together in huge volumes.

Exoplanet CI 504b — Dust disk around HL Tauri

Exploding stars scatter elements throughout the Universe - Supernovae and merging neutron stars

The fragments that became the material of our Solar System were formed in part by "supernovae" and "merging neutron stars" that scattered various elements throughout the Universe. Explosions that glowed more than one billion times brighter than the Sun instantly transformed the elements in the stars into other elements. There are two types of supernovae. The first is explosions occurring in stars far more massive than the Sun, which scatter oxygen and other elements created inside the star, and at the same time synthesize other elements, iron, which is an essential element of the human body, is formed as a result of a supernova explosion that occurs in the very small percentage of binary stars that includes a white dwarf. Heavier elements such as gold and silver are formed in neutron star mergers.

Supernova remnant M 1 (Crab Nebula) — Supernova 1994D — Optical afterglow of a gamma-ray burst from merging neutron stars

Stars that melt into the Universe - Planetary nebulae with various shapes

Not all stars meet their end in supernovae. When comparatively low-mass stars like our Sun approach the end of their lives, they slowly begin to diffuse the materials they have created into space. They gradually lose their outer envelopes which spread into the far reaches of space, leaving behind only a core. The remains of this phenomenon, referred to as a "planetary nebula", can take on many different shapes, some round and some long and narrow.

The ring nebula M 57 — Planetary nebula NGC 6302 — Various shapes of planetary nebulae

Old stars are element factories - Stars immediately before the end of their lives

In many cases, when stars grow old, they become "red giants", expanding so much that they swallow up any planets around them. At around this time, the stars begin to run out of hydrogen at their center, which is the fuel for the "nuclear fusion reactions" that allow the stars to shine, and new fusion reactions begin to take place, creating carbon and oxygen from helium. Reactions different from nuclear fusion create lead and heavy elements. Stars far heavier than the Sun become red supergiants or Wolf-Rayet stars that have lost their outer layer, and even more fusion reactions occur in the star's core, creating elements such as silicon and iron. Many of the elements essential to the existence of human beings were created inside these aging stars.

Betelgeuse (α Orionis) — A cross-section of a red giant, which is more than 10 times the mass of our Sun, on the day before a supernova explosion begins — Helium is surrounded by hydrogen — Hydrogen — Carbon+oxygen — Oxygen+ neon+ magnesium — Silicon — Iron

Betelgeuse is about 1,400 times larger than our Sun. Its circumference is about the same as Jupiter's orbit.

Jupiter's orbit

The image of the star's core is not a scale reproduction

Stars mature and shine in space - Nuclear fusion reactions and the life of a star

Fixed stars spend most of their lives as "main sequence stars", which is the name given to fixed stars that have come of age. At the center of the stars, there is a series of nuclear fusion reactions that creates a helium atom from four hydrogen atoms. This reaction generates huge volumes of light. The period of time that a given star shines as a main sequence star depends on the star's mass. Stars that are lighter than our Sun will live for more than 10 billion years, but a star with 10 times the mass of our Sun will only live for a few tens of millions of years*.

*Our Sun's life expectancy is just over 10 billion years. More than 5 billion years in the future, it will become a red giant, and in its final stages, it will become a white dwarf.

Open cluster M 45 (Pleiades) — Double Star Albireo (β Cygni) — Globular cluster M 15

The birth and growth of stars - Protostars emit jets of gas

Gas and dust clouds are the materials that form stars. Huge volumes of this material come together to form baby stars or "protostars". Some of this material is later ejected in fine but powerful streams of gas called "jets" that are emitted from protostars. Fresh material continues to collapse on the protostar, and as the core temperature and pressure increases, nuclear fusion reactions begin, and the protostar finally begins to shine as a main sequence star.

HH 30 — Orion KL Source I — HH 46 / HH 47

Elements in the constantly changing Universe - Molecular clouds: the birthplace of stars

Places in galaxies with amounts of gas and dust at particularly high levels of concentration are called "molecular clouds"*. These clouds are composed mainly of hydrogen molecules, but they also contain small amounts of water, carbon monoxide, alcohol, and other components. All of these substances are created from the diverse elements scattered through the Universe when the lives of stars from previous generations end. In other words, stars come from the elements, and return to the elements. The Earth and the Sun, the stars in the sky, and even our bodies are all part of this great cycle of elements. And if we trace them back far enough, we find that all of the substances that make up this constantly changing Universe were created in the first three minutes after the Universe was born.

*Molecular clouds appear as dark clouds, and sometimes appear to glow as they are illuminated by the light of nearby stars.

Dark nebula LDN 57 — The core of M42 (the Orion Nebula) — Part of M16 (the Eagle Nebula)

Is the Universe the only one?

Uncountable universes that theoretically exist

Some theories say our Universe was born from another universe. Many universes are born from an eternally inflating universe and our Universe is only one of them. This view of the world is one of the concepts called a "Multiverse". Superstring theory, that explains everything from particles to the Universe, supports this view. Based on the theory, our Universe has not only four dimensions (three dimensions for space and one dimension for time) but also another six dimensions which we cannot detect. The theory also predicts that over 10^{500} universes that have different sets of physical parameters could exist.

Multiverse theory changes our concept of the Universe

Do other worlds exist somewhere beyond our reach? In history, the possibility has long been considered as a mythological or religious concept without scientific basis. On the other hand, with scientific verifications scientists have determined that the Earth is just one of the planets around the Sun, the Sun is just one of the stars in the Galaxy, and the Galaxy is just one of the galaxies in our Universe. Now scientists discuss the Multiverse, not as a myth, but as a new scientific concept. Does our Universe become just one of the Multiverse?

Can we see anything beyond the Universe?

Stars are shining in the night sky. The term "light-year" (the speed of light times the travel time of the light) is a unit of length intended to describe distance to those shining stars. We can draw a 3D star map based on the light-year distances, like the figure to the right. However, this figure has a fatal inconsistency if you extend the map to very large distances. The farther away celestial bodies are located, the older the images we see are. In other words, when we observe the very distant Universe, we observe the early age of our Universe and it should be smaller than the current Universe. However, the early days of our Universe become larger in a map drawn with the light-year distances. What is wrong? The problem is the light-year distance as a unit of length. It does not matter if our Universe is not expanding. But in our expanding Universe, while light is traveling from one part to another, the separation of the two points keeps expanding. Therefore the resulting "distance" could be something different from the type of "distance" we're used to in our daily life. In this diagram of our Universe, we avoid this problem by plotting observable celestial bodies on a graph that has two independent axes, time and distance. How we can create a reasonable figure of our Universe based on our limited observable Universe is an important issue in science. Scientists wrestled with the issue, and changed the paradigm of the world as a result. Today, scientists consider the world that we cannot observe in addition to what we can observe. The new scientific concept of the Multiverse is one of the answers that scientists have proposed. Investigating the nature of the Multiverse, we may discover a new world based on currently-unknown theorems.

The oldest scene is the vastest one!

Time — Space — Teardrop shape — Inverted cone

Why is there something rather than nothing?

The size of a thumbtack hole can be thought of as the size of space just after it was born.

A thumbtack hole is about 10 million times the size of a hydrogen atom.

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