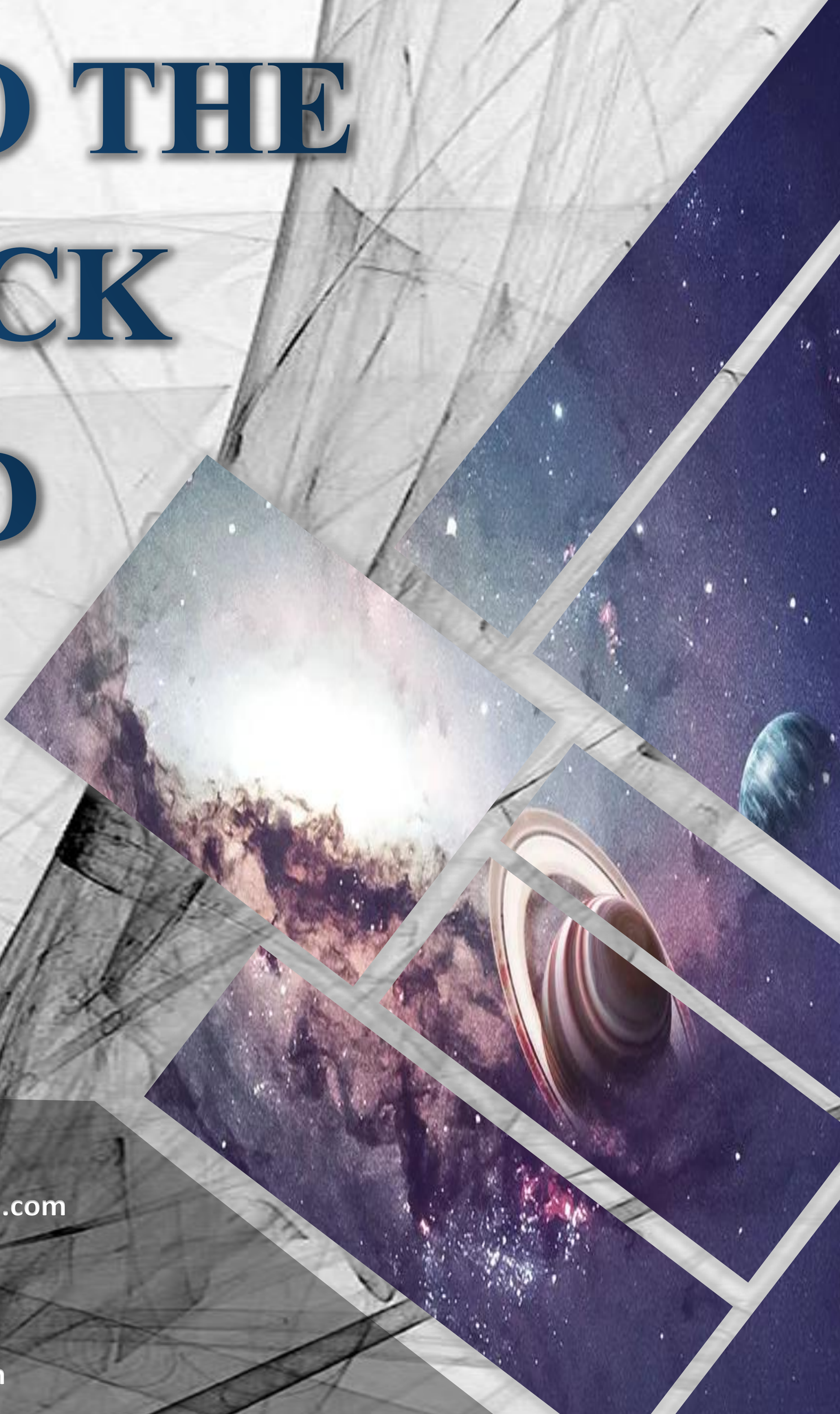
INTO THE BLACK VOID



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Contents

❖ *INTRODUCTION*

Our Solar System:

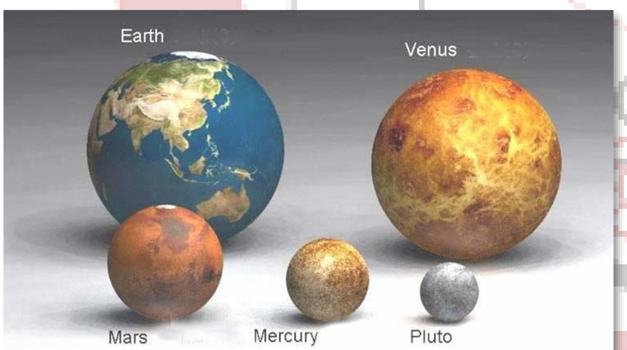
There are many planetary systems in the universe, with planets orbiting host stars. Our planetary system is called “the solar system” because we use the word “solar” to describe things related to our star, after the Latin word for Sun, "solis." (1)

❖ *CONTENTS*

- Size and Distance
- Moons
- Formation
- Structure (1)

❖ *Size and Distance*

Our solar system extends much farther than the eight planets that orbit the Sun. The solar system also includes the Kuiper Belt [1] that lies past Neptune's orbit. This is a sparsely occupied ring of icy bodies, almost all smaller than the most popular Kuiper Belt Object – dwarf planet Pluto.



Beyond the fringes of the Kuiper Belt is the Oort Cloud. This giant spherical shell surrounds our solar system. It has never been directly observed, but its existence is predicted based on mathematical models and observations of comets that likely originate there.

The Oort Cloud is made of icy pieces of space debris - some bigger than mountains – orbiting our Sun as far as 1.6 light-years away. This shell of material is thick, extending from 5,000 astronomical units to 100,000 astronomical units. One astronomical unit (or AU) is the distance from the Sun to Earth, or about 93 million miles (150 million kilometers). The Oort Cloud is the boundary of the Sun's gravitational influence, where orbiting objects can turn around and return closer to our Sun.

[1] **Kuiper Belt** is a doughnut-shaped region of icy bodies extending far beyond the orbit of Neptune.

The Sun's heliosphere doesn't extend quite as far. The heliosphere is the bubble created by the solar wind – a stream of electrically charged gas blowing outward from the Sun in all directions. The boundary where the solar wind is abruptly slowed by pressure from interstellar gases is called the termination shock. This edge occurs between 80-100 astronomical units.

Two NASA spacecraft launched in 1977 have crossed the termination shock: Voyager 1 in 2004 and Voyager 2 in 2007. Voyager 1 went interstellar in 2012 and Voyager 2 joined it in 2018. But it will be many thousands of years before the two Voyagers exit the Oort Cloud. (1)

❖ *Formation*

Our solar system formed about 4.5 billion years ago from a dense cloud of interstellar gas and dust. The cloud collapsed, possibly due to the shockwave of a nearby exploding star, called a supernova. When this dust cloud collapsed, it formed a solar nebula – a spinning, swirling disk of material.

At the center, gravity pulled more and more material in. Eventually, the pressure in the core was so great that hydrogen atoms began to combine and form helium, releasing a tremendous amount of energy. With that, our Sun was born, and it eventually amassed more than 99% of the available matter.

Matter farther out in the disk was also clumping together. These clumps smashed into one another, forming larger and larger objects. Some of them grew big enough for their gravity to shape them into spheres, becoming planets, dwarf planets, and large moons. In other cases, planets did not form: the asteroid belt is made of bits and pieces of the early solar system that could never quite come together into a planet. Other smaller leftover pieces became asteroids, comets, meteoroids, and small, irregular moons. (1)

❖ *Structure*

The order and arrangement of the planets and other bodies in our solar system is due to the way the solar system formed. Nearest to the Sun, only rocky material could withstand the heat when the solar system was young. For this reason, the first four planets – Mercury, Venus, Earth, and Mars – are terrestrial planets. They are all small with solid, rocky surfaces.

Meanwhile, materials we are used to seeing as ice, liquid, or gas settled in the outer regions of the young solar system. Gravity pulled these materials together, and that is where we find gas giants Jupiter and Saturn, and the ice giants Uranus and Neptune. (1)

❖ *EXOPLANETS*

An exoplanet is any planet beyond our solar system. Most orbit other stars, but free-floating exoplanets, called rogue planets, are untethered to any star. We've confirmed more than 5,200 out of the billions of exoplanets that we believe exist. Exoplantes consists of various material that doesn't even exist in earth or earth crusts. (1)

❖ *Overview*

Most of the exoplanets discovered so far are in a relatively small region of our galaxy, the Milky Way. ("Small" meaning within thousands of light-years of our solar system; one light-year equals 5.88 trillion miles, or 9.46 trillion kilometers.) Even the closest known exoplanet to Earth, Proxima Centauri b, is still about 4 light-years away. We know there are more planets than stars in the galaxy.

By measuring exoplanets' sizes (diameters) and masses (weights), we can see compositions ranging from rocky (like Earth and Venus) to gas-rich (like Jupiter and Saturn). Some planets may be dominated by water or ice, while others are dominated by iron or carbon. We've identified lava worlds covered in molten seas, puffy planets the density of Styrofoam and dense cores of planets still orbiting their stars. (1)

❖ *Exoplanet discovery – and mystery*

The first exoplanets were discovered in the early 1990s, but the first exoplanet to burst upon the world stage was 51 Pegasi b, a "hot Jupiter" orbiting a Sun-like star 50 light-years away. The watershed year was 1995. Since then we've discovered thousands more.

Size and mass play a crucial role in determining planet types. There are also varieties within the size/mass classifications. Scientists also have noted what seems to be a strange gap in planet sizes. It's been dubbed the "radius valley," or the Fulton gap, after Benjamin Fulton, lead author on a paper describing it. Data from NASA's Kepler spacecraft showed that planets of a certain size-range are rare – those between 1.5 and 2 times the size (diameter) of Earth, which would place them among the super-Earths. It's possible that this represents a critical size in planet formation: Planets that reach this size quickly attract thick atmospheres of hydrogen and helium gas, and balloon up into gaseous planets, while planets smaller than this limit are not large enough to hold such an atmosphere and remain primarily rocky, terrestrial bodies. On the other hand, the smaller planets that orbit close to their stars could be the cores of Neptune-like worlds that had their atmospheres stripped away.

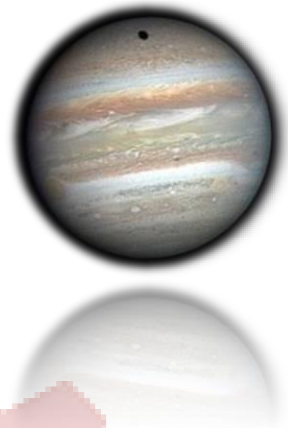
Explaining the Fulton gap will require a far better understanding of how planetary systems form. (1)

❖ *Types of exoplanets*

Each planet type varies in interior and exterior appearance depending on composition.

- Gas giants
- Neptunian planet
- Super earths
- Terrestrial planets (1)

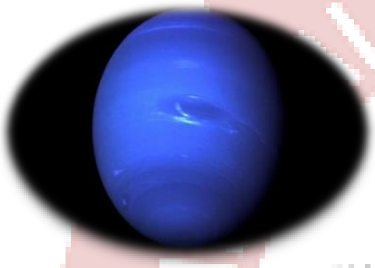
❖ *Gas giants*



Gas giants are planets the size of Saturn or Jupiter, the largest planet in our solar system, or much, much larger.

More variety is hidden within these broad categories. Hot Jupiters, for instance, were among the first planet types found – gas giants orbiting so closely to their stars that their temperatures soar into the thousands of degrees (Fahrenheit or Celsius). (1)

❖ *Neptunian planet*



Neptunian planets are similar in size to Neptune or Uranus in our solar system. They likely have a mixture of interior compositions, but all will have hydrogen and helium-dominated outer atmospheres and rocky cores. We're also discovering mini-Neptunes, planets smaller than Neptune and bigger than Earth. No planets of this size or type exist in our solar system. (1)

❖ *Super-Earths*

Super-Earths are typically terrestrial planets that may or may not have atmospheres. They are more massive than Earth, but lighter than Neptune. (1)

❖ *Terrestrial planets*

Terrestrial planets are Earth sized and smaller, composed of rock, silicate, water or carbon. Further investigation will determine whether some of them possess atmospheres, oceans or other signs of habitability. (1)

❖ *GALAXY*

A galaxy is a huge collection of gas, dust, and billions of stars and their solar systems, all held together by gravity. We live on a planet called Earth that is part of our solar system. But where is our solar system? It's a small part of the Milky Way Galaxy.

A **galaxy** is a huge collection of gas, dust, and billions of stars and their solar systems. A galaxy is held together by gravity. Our galaxy, the Milky Way, also has a supermassive black hole in the middle. When you look up at stars in the night sky, you're seeing other stars in the Milky Way. If it's really dark, far away from lights from cities and houses, you can even see the dusty bands of the Milky Way stretch across the sky. (2)

❖ *Types of galaxies*

- Elliptical galaxy
- Irregular galaxy
- Spiral galaxy
- Barred spiral galaxy
- Andromeda galaxy
- Quasar (2)

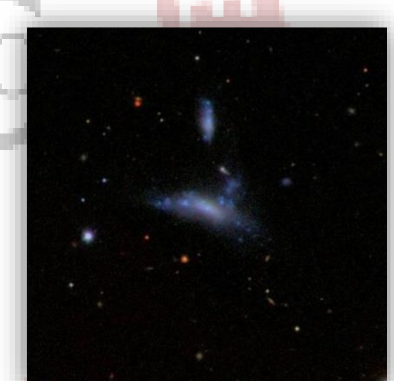
❖ *Elliptical galaxy*

An elliptical galaxy is a type of galaxy with an approximately ellipsoidal shape and a smooth, nearly featureless image. They are one of the four main classes of galaxy described by Edwin Hubble in his Hubble sequence and 1936 work The Realm of the Nebulae, along with spiral and lenticular galaxies. Elliptical (E) galaxies are, together with lenticular galaxies (S0) with their large-scale disks, and ES galaxies with their intermediate scale disks, a subset of the "early-type" galaxy population.

Most elliptical galaxies are composed of older, low-mass stars, with a sparse interstellar medium, and they tend to be surrounded by large numbers of globular clusters. Star formation activity in elliptical galaxies is typically minimal; they may, however, undergo brief periods of star formation when merging with other galaxies. Elliptical galaxies are believed to make up approximately 10–15% of galaxies in the Virgo Supercluster, and they are not the dominant type of galaxy in the universe overall.They are preferentially found close to the centers of galaxy clusters.

Elliptical galaxies range in size from dwarf ellipticals with tens of millions of stars, to supergiants of over one hundred trillion stars that dominate their galaxy clusters. Originally, Edwin Hubble hypothesized that elliptical galaxies evolved into spiral galaxies, which was later discovered to be false, although the accretion of gas and smaller galaxies may build a disk around a pre-existing ellipsoidal structure. Stars found inside of elliptical galaxies are on average much older than stars found in spiral galaxies. (3)

❖ *Irregular Galaxies*



Unlike elliptical or spiral galaxies, irregular galaxies have no visible pattern. These are the smallest of the galaxies and may contain as few as 1 million stars. Some astronomers believe that irregular galaxies may act as building blocks from which other galaxies are formed.

How did galaxies originate? Astronomers believe that after the big bang, the explosion which began the universe 10 billion to 20 billion years ago, gravity began to compress masses of free-floating gas. Two main theories, bottom-up and top-down, explain what happened next. According to bottom-up theories, clusters began to form and assembled together into the larger units we know as galaxies. Top-down theories suggest that galaxies formed first, and the stars and other objects within them were subsequently produced. (3)

❖ *Spiral galaxy*

Spiral galaxies form a class of galaxy originally described by Edwin Hubble in his 1936 work The Realm of the Nebulae and, as such, form part of the Hubble sequence. Most spiral galaxies consist of a flat, rotating disk containing stars, gas and dust, and a central concentration of stars known as the bulge. These are often surrounded by a much fainter halo of stars, many of which reside in globular clusters.

Spiral galaxies are named by their spiral structures that extend from the center into the galactic disc. The spiral arms are sites of ongoing star formation and are brighter than the surrounding disc because of the young, hot OB stars that inhabit them.

Roughly two-thirds of all spirals are observed to have an additional component in the form of a bar-like structure, extending from the central bulge, at the ends of which the spiral arms begin. The proportion of barred spirals relative to barless spirals has likely changed over the history of the universe, with only about 10% containing bars about 8 billion years ago, to roughly a quarter 2.5 billion years ago, until present, where over two-thirds of the galaxies in the visible universe (Hubble volume) have bars.

The Milky Way is a barred spiral, although the bar itself is difficult to observe from Earth's current position within the galactic disc. The most convincing evidence for the stars forming a bar in the Galactic Center comes from several recent surveys, including the Spitzer Space Telescope.

Together with irregular galaxies, spiral galaxies make up approximately 60% of galaxies in today's universe. They are mostly found in low-density regions and are rare in the centers of galaxy clusters. (3)

❖ *Barred spiral galaxy*

A barred spiral galaxy is a spiral galaxy with a central bar-shaped structure composed of stars. Bars are found in about two thirds of all spiral galaxies in the local universe, and generally affect both the motions of stars and interstellar gas within spiral galaxies and can affect spiral arms as well. The Milky Way Galaxy, where the Solar System is located, is classified as a barred spiral galaxy.

Edwin Hubble classified spiral galaxies of this type as "SB" (spiral, barred) in his Hubble sequence and arranged them into sub-categories based on how open the arms of the spiral are. SBa types feature tightly bound arms, while SBc types are at the other extreme and have loosely bound arms. SBb-type galaxies lie in between the two. SB0 is a barred lenticular galaxy. A new type, SBm, was subsequently created to describe somewhat irregular barred spirals, such as the Magellanic Clouds, which were once classified as irregular galaxies, but have since been found to contain barred spiral structures. Among other types in Hubble's classifications for the galaxies are the spiral galaxy, elliptical galaxy and irregular galaxy.

Although theoretical models of galaxy formation and evolution had not previously expected galaxies becoming stable enough to host bars very early in the universe's history, evidence has recently emerged of the existence of numerous spiral galaxies in the early universe. (3)

Andromeda Galaxy

The Andromeda Galaxy is a barred spiral galaxy and is the nearest major galaxy to the Milky Way. It was originally named the Andromeda Nebula and is cataloged as Messier 31, M31, and NGC 224. Andromeda has a D25 isophotal diameter of about 46.56 kiloparsecs (152,000 light-years) and is approximately 765 kpc (2.5 million light-years) from Earth. The galaxy's name stems from the area of Earth's sky in which it appears, the constellation of Andromeda, which itself is named after the princess who was the wife of Perseus in Greek mythology.

The virial mass of the Andromeda Galaxy is of the same order of magnitude as that of the Milky Way, at 1 trillion solar masses (2.0×1042 kilograms). The mass of either galaxy is difficult to estimate with any accuracy, but it was long thought that the Andromeda Galaxy was more massive than the Milky Way by a margin of some 25% to 50%. However, this has been called into question by early 21st-century studies indicating a possibly lower mass for the Andromeda Galaxy and a higher mass for the Milky Way. The Andromeda Galaxy has a diameter of about 46.56 kpc (152,000 ly), making it the largest member of the Local Group of galaxies in terms of extension.

The Milky Way and Andromeda galaxies are expected to collide with each other in around 4–5 billion years, merging to potentially form a giant elliptical galaxy or a large lenticular galaxy.

With an apparent magnitude of 3.4, the Andromeda Galaxy is among the brightest of the Messier objects, and is visible to the naked eye from Earth on moonless nights, even when viewed from areas with moderate light pollution. (3)

❖ Quasar

A quasar (/ˈkweɪzɑːr/ KWAY-zar) is an extremely luminous active galactic nucleus (AGN). It is sometimes known as a quasi-stellar object, abbreviated QSO. The emission from an AGN is powered by a supermassive black hole with a mass ranging from millions to tens of billions of solar masses, surrounded by a gaseous accretion disc. Gas in the disc falling towards the black hole heats up and releases energy in the form of electromagnetic radiation. The radiant energy of quasars is enormous; the most powerful quasars have luminosities thousands of times greater than that of a galaxy such as the Milky Way. Quasars are usually categorized as a subclass of the more general category of AGN. The redshifts of quasars are of cosmological origin.

The term *quasar* originated as a contraction of "quasi-stellar [star-like] radio source"—because they were first identified during the 1950s as sources of radio-wave emission of unknown physical origin—and when identified in photographic images at visible wavelengths, they resembled faint, star-like points of light. High-resolution images of quasars, particularly from the Hubble Space Telescope, have shown that quasars occur in the centers of galaxies, and that some host galaxies are strongly interacting or merging galaxies. As with other categories of AGN, the observed properties of a quasar depend on many factors, including the mass of the black hole, the rate of gas accretion, the orientation of the accretion disc relative to the observer, the presence or absence of a jet, and the degree of obscuration by gas and dust within the host galaxy.

About a million quasars have been identified with reliable spectroscopic redshifts, and between 2-3 million identified in photometric catalogs. The nearest known quasar is about 600 million light-years from Earth. The record for the most distant known quasar continues to change. In 2017, quasar ULAS J1342+0928 was detected at redshift z = 7.54. Light observed from this 800-million-solar-mass quasar was emitted when the universe was only 690 million years old. In 2020, quasar Pōniuāʻena was detected from a time only 700 million years after the Big Bang, and with an estimated mass of 1.5 billion times the mass of the Sun. In early 2021, the quasar QSO J0313–1806, with a 1.6-billion-solar-mass black hole, was reported at z = 7.64, 670 million years after the Big Bang.

Quasar discovery surveys have shown that quasar activity was more common in the distant past; the peak epoch was approximately 10 billion years ago. Concentrations of multiple quasars are known as large quasar groups and may constitute some of the largest known structures in the universe if the observed groups are good tracers of mass distribution. (3)

❖ *Nebula*

A nebula (Latin for 'cloud, fog'; pl.: nebulae, nebula, or nebulas) is a distinct luminescent part of interstellar medium, which can consist of ionized, neutral, or molecular hydrogen and also cosmic dust. Nebulae are often star-forming regions, such as in the "Pillars of Creation" in the Eagle Nebula. In these regions, the formations of gas, dust, and other materials "clump" together to form denser regions, which attract further matter and eventually become dense enough to form stars. The remaining material is then thought to form planets and other planetary system objects.

Most nebulae are of vast size; some are hundreds of light-years in diameter. A nebula that is visible to the human eye from Earth would appear larger, but no brighter, from close by. The Orion Nebula, the brightest nebula in the sky and occupying an area twice the angular diameter of the full Moon, can be viewed with the naked eye but was missed by early astronomers. Although denser than the space surrounding them, most nebulae are far less dense than any vacuum created on Earth (105 to 107 molecules per cubic centimeter) – a nebular cloud the size of the Earth would have a total mass of only a few kilograms. Earth's air has a density of approximately 1019 molecules per cubic centimeter; by contrast,

the densest nebulae can have densities of 104 molecules per cubic centimeter. Many nebulae are visible due to fluorescence caused by embedded hot stars, while others are so diffused that they can be detected only with long exposures and special filters. Some nebulae are variably illuminated by T Tauri variable stars.

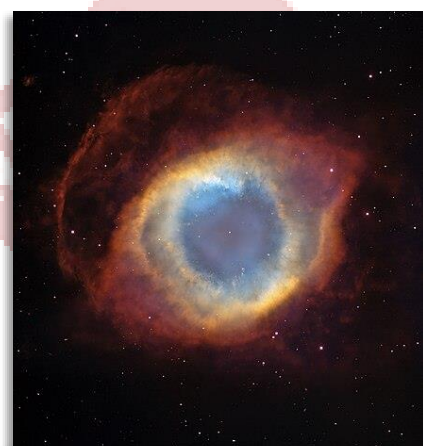
Originally, the term "nebula" was used to describe any diffused astronomical object, including galaxies beyond the Milky Way. The Andromeda Galaxy, for instance, was once referred to as the Andromeda Nebula (and spiral galaxies in general as "spiral nebulae") before the true nature of galaxies was confirmed in the early 20th century by Vesto Slipher, Edwin Hubble, and others. Edwin Hubble discovered that most nebulae are associated with stars and illuminated by starlight. He also helped categorize nebulae based on the type of light spectra they produced. (3)

❖ *Types of nebula*

- Helix nebula
- Crab nebula
- Orion nebula
- Horsehead nebula
- Eagle nebula (3)

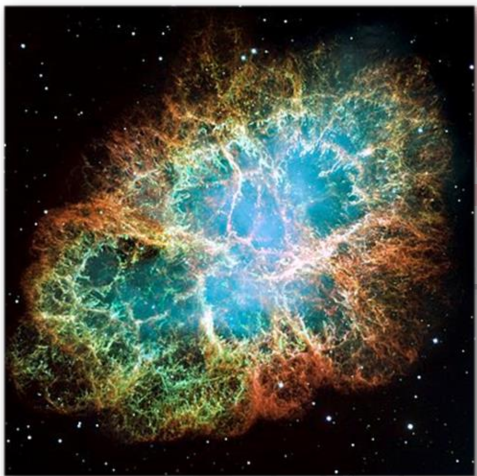
❖ *Helix nebula*

The Helix Nebula (also known as NGC 7293 or Caldwell 63) is a planetary nebula (PN) located in the constellation Aquarius. Discovered by Karl Ludwig Harding, most likely before 1824, this object is one of the closest of all the bright planetary nebulae to Earth. The distance, measured by the Gaia mission, is 655±13 light-years. It is similar in appearance to the Cat's Eye Nebula and the Ring Nebula, whose size, age, and physical characteristics are similar to the Dumbbell Nebula, varying only in its relative proximity and the appearance from the equatorial viewing angle. The Helix Nebula has sometimes been referred to as the "Eye of God" in pop culture, as well as the "Eye of Sauron". (3)



❖ *Crab Nebula*

The Crab Nebula (catalogue designations M1, NGC 1952, Taurus A) is a supernova remnant and pulsar wind nebula in the constellation of Taurus. The common name comes from a drawing that somewhat resembled a crab with arms produced by William Parsons, 3rd Earl of Rosse, in 1842 or 1843 using a 36-inch (91 cm) telescope. The nebula was discovered by English astronomer John Bevis in 1731. It corresponds with a bright supernova recorded by Chinese astronomers in 1054 as a guest star. The nebula was the first astronomical object identified that corresponds with a historically-observed supernova explosion.



At an apparent magnitude of 8.4, comparable to that of Saturn's moon Titan, it is not visible to the naked eye but can be made out using binoculars under favourable conditions. The nebula lies in the Perseus Arm of the Milky Way galaxy, at a distance of about 2.0 kiloparsecs (6,500 ly) from Earth. It has a diameter of 3.4 parsecs (11 ly), corresponding to an apparent diameter of some 7 arcminutes, and is expanding at a rate of about 1,500 kilometres per second (930 mi/s), or 0.5% of the speed of light.

At the center of the nebula lies the Crab Pulsar, a neutron star 28–30 kilometres (17–19 mi) across with a spin rate of 30.2 times per second, which emits pulses of radiation from gamma rays to radio waves. At X-ray and gamma ray energies above 30 keV, the Crab Nebula is generally the brightest persistent gamma-ray source in the sky, with measured flux extending to above 10 TeV. The nebula's radiation allows detailed study of celestial bodies that occult it. In the 1950s and 1960s, the Sun's corona was mapped from observations of the Crab Nebula's radio waves passing through it, and in 2003, the thickness of the atmosphere of Saturn's moon Titan was measured as it blocked out X-rays from the nebula. (3)

❖ Orion Nebula

The Orion Nebula (also known as Messier 42, M42, or NGC 1976) is a diffuse nebula situated in the Milky Way, being south of Orion's Belt in the constellation of Orion,[b] and is known as the middle "star" in the "sword" of Orion. It is one of the brightest nebulae and is visible to the naked eye in the night sky with apparent magnitude 4.0. It is 1,344 ± 20 light-years (412.1 ± 6.1 pc) away and is the closest region of massive star formation to Earth. The M42 nebula is estimated to be 24 light-years across (so its apparent size from Earth is approximately 1 degree). It has a mass of about 2,000 times that of the Sun. Older texts frequently refer to the Orion Nebula as the Great Nebula in Orion or the Great Orion Nebula.

The Orion Nebula is one of the most scrutinized and photographed objects in the night sky and is among the most intensely studied celestial features. The nebula has revealed much about the process of how stars and planetary systems are formed from collapsing clouds of gas and dust. Astronomers have directly observed protoplanetary disks and brown dwarfs within the nebula, intense and turbulent motions of the gas, and the photo-ionizing effects of massive nearby stars in the nebula. (3)

❖ Horsehead Nebula

The Horsehead Nebula (also known as Barnard 33 or B33) is a small dark nebula in the constellation Orion. The nebula is located just to the south of Alnitak, the easternmost star of Orion's Belt, and is part of the much larger Orion molecular cloud complex. It appears within the southern region of the dense dust cloud known as Lynds 1630, along the edge of the much larger, active star-forming H II region called IC 434.

The Horsehead Nebula is approximately 422 parsecs or 1,375 light-years from Earth. It is one of the most identifiable nebulae because of its resemblance to a horse's head.

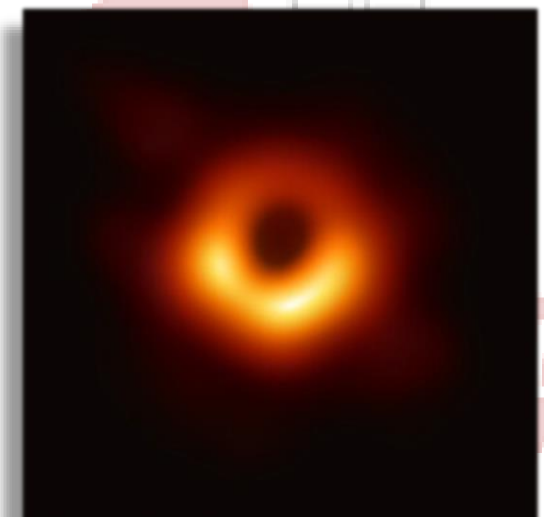
Using NASA's James Webb Space Telescope, astronomers have captured the nebula's "mane" in unprecedented detail, revealing the complexity of the photodissociation region where ultraviolet light interacts with gas and dust. (3)

❖ Eagle Nebula

The Eagle Nebula (catalogued as Messier 16 or M16, and as NGC 6611, and also known as the Star Queen Nebula) is a young open cluster of stars in the constellation Serpens, discovered by Jean-Philippe de Cheseaux in 1745–46. Both the "Eagle" and the "Star Queen" refer to visual impressions of the dark silhouette near the center of the nebula, an area made famous as the "Pillars of Creation" imaged by the Hubble Space Telescope. The nebula contains several active star-forming gas and dust regions, including the aforementioned Pillars of Creation. The Eagle Nebula lies in the Sagittarius Arm of the Milky Way. (3)

❖ Black hole

A black hole is a region of spacetime where gravity is so strong that nothing, including light and other electromagnetic waves, is capable of possessing enough energy to escape it. Einstein's theory of general relativity predicts that a sufficiently compact mass can deform spacetime to form a black hole. The boundary of no escape is called the event horizon. A black hole has a great effect on the fate and circumstances of an object crossing it, but it has no locally detectable features according to general relativity. In many ways, a black hole acts like an ideal black body, as it reflects no light. Quantum field theory in curved spacetime predicts that event horizons emit Hawking radiation, with the same spectrum as a black body of a temperature inversely proportional to its mass. This temperature is of the order of billionths of a kelvin for stellar black holes, making it essentially impossible to observe directly.



Objects whose gravitational fields are too strong for light to escape were first considered in the 18th century by John Michell and Pierre-Simon Laplace. In 1916, Karl Schwarzschild found the first modern solution of general relativity that would characterize a black hole. David Finkelstein, in 1958, first published the interpretation of "black hole" as a region of space from which nothing can escape. Black holes were long considered a mathematical curiosity; it was not until the 1960s that theoretical work showed they were a generic prediction of general relativity. The discovery of neutron stars by Jocelyn Bell Burnell in 1967 sparked interest in gravitationally collapsed compact objects as a possible astrophysical reality. The first black hole known was Cygnus X-1, identified by several researchers independently in 1971.

Black holes of stellar mass form when massive stars collapse at the end of their life cycle. After a black hole has formed, it can grow by absorbing mass from its surroundings. Supermassive black holes of millions of solar masses ($M_\odot$) may form by absorbing other stars and merging with other black holes, or via direct collapse of gas clouds. There is consensus that supermassive black holes exist in the centres of most galaxies.

The presence of a black hole can be inferred through its interaction with other matter and with electromagnetic radiation such as visible light. Any matter that falls toward a black hole can form an external accretion disk heated by friction, forming quasars, some of the brightest objects in the universe. Stars passing too close to a supermassive black hole can be shredded into streamers that shine very brightly before being "swallowed." If other stars are orbiting a black hole, their orbits can be used to determine the black hole's mass and location. Such observations can be used to exclude possible alternatives such as neutron stars. In this way, astronomers have identified numerous stellar black hole candidates in binary systems and established that the radio source known as Sagittarius A*, at the core of the Milky Way galaxy, contains a supermassive black hole of about 4.3 million solar masses. (3)

❖ *Types of blackhole*

- Steller blackhole
- Intermediate blackhole
- Supermassive blackhole (3)

❖ *Stellar black hole*

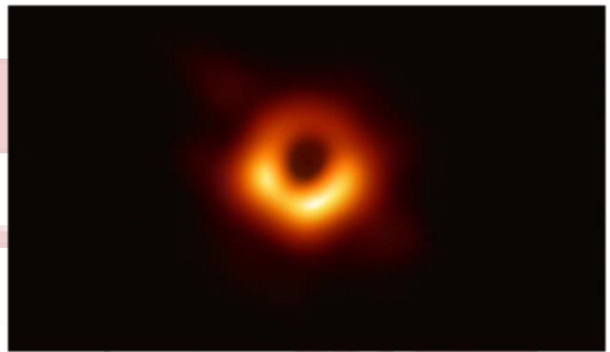
A stellar black hole (or stellar-mass black hole) is a black hole formed by the gravitational collapse of a star. They have masses ranging from about 5 to several tens of solar masses. They are the remnants of supernova explosions, which may be observed as a type of gamma ray burst. These black holes are also referred to as collapsars. (3)

❖ *Intermediate-mass black hole*

An intermediate-mass black hole (IMBH) is a class of black hole with mass in the range 102–105 solar masses: significantly higher than stellar black holes but lower than the 105–109 solar mass supermassive black holes. Several IMBH candidate objects have been discovered in the Milky Way galaxy and others nearby, based on indirect gas cloud velocity and accretion disk spectra observations of various evidentiary strength. (3)

❖ Supermassive black hole

A supermassive black hole (SMBH or sometimes SBH)[a] is the largest type of black hole, with its mass being on the order of hundreds of thousands, or millions to billions, of times the mass of the Sun ($M\odot$). Black holes are a class of astronomical objects that have undergone gravitational collapse, leaving behind spheroidal regions of space from which nothing can escape, including light. Observational evidence indicates that almost every large galaxy has a supermassive black hole at its center. For example, the Milky Way galaxy has a supermassive black hole at its center, corresponding to the radio source Sagittarius A*. Accretion of interstellar gas onto supermassive black holes is the process responsible for powering active galactic nuclei (AGNs) and quasars.



Two supermassive black holes have been directly imaged by the Event Horizon Telescope: the black hole in the giant elliptical galaxy Messier 87 and the black hole at the Milky Way's center (Sagittarius A*). (3)

❖ Dark matter

In astronomy, dark matter is a hypothetical form of matter that appears not to interact with light or the electromagnetic field. Dark matter is implied by gravitational effects which cannot be explained by general relativity unless more matter is present than can be seen. Such effects occur in the context of formation and evolution of galaxies, gravitational lensing, the observable universe's current structure, mass position in galactic collisions, the motion of galaxies within galaxy clusters, and cosmic microwave background anisotropies.

In the standard lambda-CDM model of cosmology, the mass–energy content of the universe is 5% ordinary matter, 26.8% dark matter, and 68.2% a form of energy known as dark energy. Thus, dark matter constitutes 85%[a] of the total mass, while dark energy and dark matter constitute 95% of the total mass–energy content.

Dark matter is not known to interact with ordinary baryonic matter and radiation except through gravity, making it difficult to detect in the laboratory. The most prevalent explanation is that dark matter is some as-yet-undiscovered subatomic particle,[c] such as weakly interacting massive particles (WIMPs) or axions. The other main possibility is that dark matter is composed of primordial black holes.

Dark matter is classified as "cold", "warm", or "hot" according to its velocity (more precisely, its free streaming length). Recent models have favored a cold dark matter scenario, in which structures emerge by the gradual accumulation of particles, but after a half century of fruitless dark matter particle searches, more recent gravitational wave and James Webb Space Telescope observations have considerably strengthened the case for primordial and direct collapse black holes.

Although the astrophysics community generally accepts dark matter's existence, a minority of astrophysicists, intrigued by specific observations that are not well-explained by ordinary dark matter, argue for various modifications of the standard laws of general relativity. These include modified Newtonian dynamics, tensor–vector–scalar gravity, or entropic gravity. So far none of the proposed modified gravity theories can successfully describe every piece of observational evidence at the same time, suggesting that even if gravity has to be modified, some form of dark matter will still be required. (3)

❖ *SPACE EXPLORATION*

Space exploration is the use of astronomy and space technology to explore outer space. While the exploration of space is currently carried out mainly by astronomers with telescopes, its physical exploration is conducted both by uncrewed robotic space probes and human spaceflight. Space exploration, like its classical form astronomy, is one of the main sources for space science.

While the observation of objects in space, known as astronomy, predates reliable recorded history, it was the development of large and relatively efficient rockets during the mid-twentieth century that allowed physical space exploration to become a reality. Common rationales for exploring space include advancing scientific research, national prestige, uniting different nations, ensuring the future survival of humanity, and developing military and strategic advantages against other countries.

The early era of space exploration was driven by a "Space Race" between the Soviet Union and the United States. A driving force of the start of space exploration was during the Cold War. After the ability to create nuclear weapons, the narrative of defense/offense left land and the power to control the air became the

focus. Both the Soviet and the U.S. were fighting to prove their superiority in technology through exploring the unknown: space. In fact, the reason NASA was made was due to the response of Sputnik I. The launch of the first human-made object to orbit Earth, the Soviet Union's Sputnik 1, on 4 October 1957, and the first Moon landing by the American Apollo 11 mission on 20 July 1969 are often taken as landmarks for this initial period. The Soviet space program achieved many of the first milestones, including the first living being in orbit in 1957, the first human spaceflight (Yuri Gagarin aboard Vostok 1) in 1961, the first spacewalk (by Alexei Leonov) on 18 March 1965, the first automatic landing on another celestial body in 1966, and the launch of the first space station (Salyut 1) in 1971. After the first 20 years of exploration, focus shifted from one-off flights to renewable hardware, such as the Space Shuttle program, and from competition to cooperation as with the International Space Station (ISS). (3)

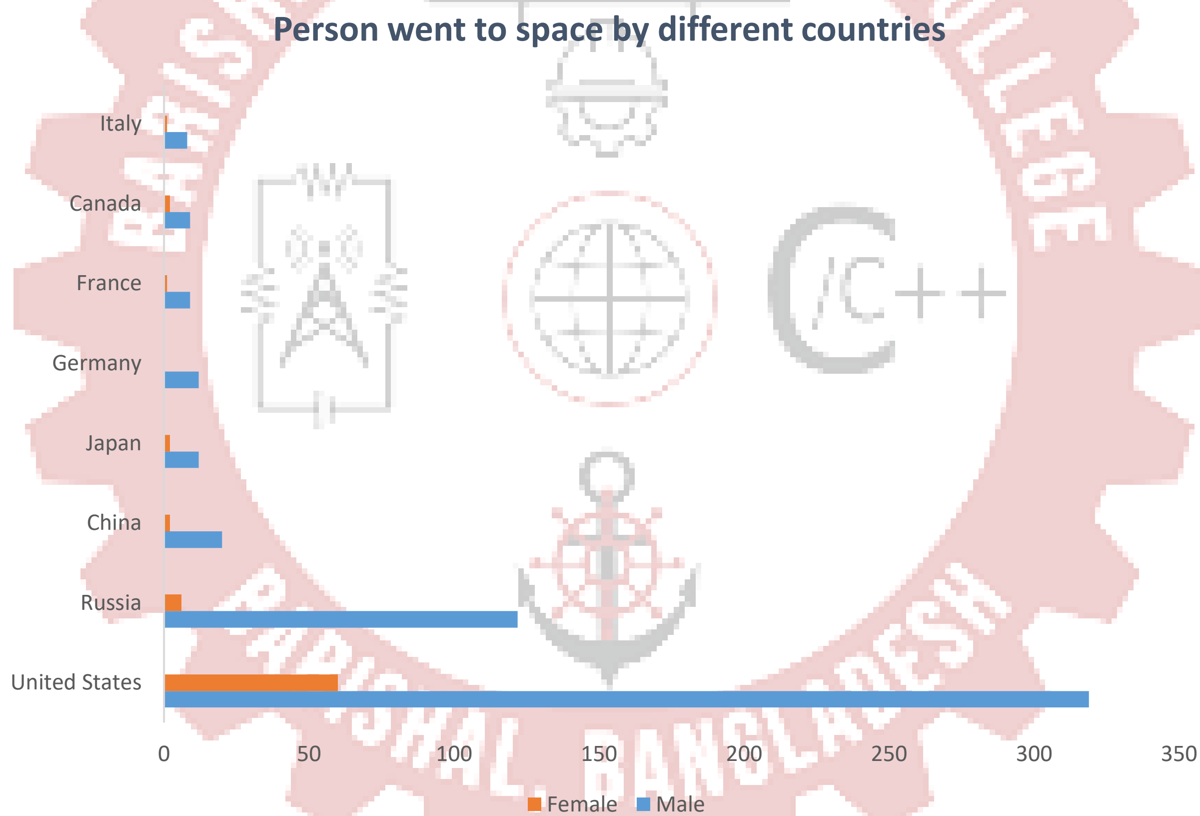


Fig: Space Exploration By Countries

❖ *SATELLITE*

A satellite or artificial satellite[a] is an object, typically a spacecraft, placed into orbit around a celestial body. Satellites have a variety of uses, including communication relay, weather forecasting, navigation (GPS), broadcasting, scientific research, and Earth observation. Additional military uses are reconnaissance, early warning, signals intelligence and, potentially, weapon delivery. Other satellites include the final rocket stages that place satellites in orbit and formerly useful satellites that later become defunct.

Except for passive satellites, most satellites have an electricity generation system for equipment on board, such as solar panels or radioisotope thermoelectric generators (RTGs). Most satellites also have a method of communication to ground stations, called transponders. Many satellites use a standardized bus to save cost and work, the most popular of which are small CubeSats. Similar satellites can work together as groups, forming constellations. Because of the high launch cost to space, most satellites are designed to be as lightweight and robust as possible. Most communication satellites are radio relay stations in orbit and carry dozens of transponders, each with a bandwidth of tens of megahertz.

Satellites are placed from the surface to the orbit by launch vehicles, high enough to avoid orbital decay by the atmosphere. Satellites can then change or maintain the orbit by propulsion, usually by chemical or ion thrusters. As of 2018, about 90% of the satellites orbiting the Earth are in low Earth orbit or geostationary orbit; geostationary means the satellites stay still in the sky (relative to a fixed point on the ground). Some imaging satellites chose a Sun-synchronous orbit because they can scan the entire globe with similar lighting. As the number of satellites and space debris around Earth increases, the threat of collision has become more severe. A small number of satellites orbit other bodies (such as the Moon, Mars, and the Sun) or many bodies at once (two for a halo orbit, three for a Lissajous orbit).

Earth observation satellites gather information for reconnaissance, mapping, monitoring the weather, ocean, forest, etc. Space telescopes take advantage of outer space's near perfect vacuum to observe objects with the entire electromagnetic spectrum. Because satellites can see a large portion of the Earth at once, communications satellites can relay information to remote places. The signal delay from satellites and their orbit's predictability are used in satellite navigation systems, such as GPS. Space probes are satellites designed for robotic space exploration outside of Earth, and space stations are in essence crewed satellites.

The first artificial satellite launched into the Earth's orbit was the Soviet Union's Sputnik 1, on October 4, 1957. As of December 31, 2022, there are 6,718 operational satellites in the Earth's orbit, of which 4,529 belong to the United States (3,996 commercial), 590 belong to China, 174 belong to Russia, and 1,425 belong to other nations. (3)

List of Top 10 Countries with Most Satellite Launches

As the demand for satellite services grows, so does the need for reliable launch capabilities. Several countries have invested heavily in space exploration and satellite technology, leading to a competitive landscape in the realm of satellite launches. In the following we will discuss the list of countries with the most satellite launches, showcasing their contributions to space exploration and technological advancement. (3)

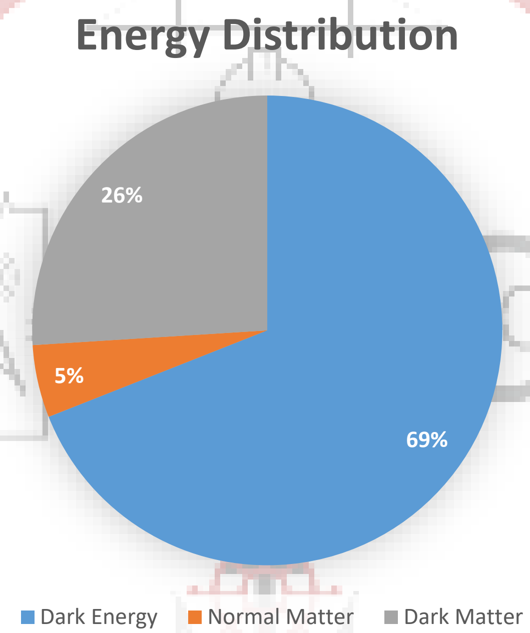
- United States : 4 511 satellites.
- China : 586 satellites.
- United Kingdom : 561 satellites.
- Russia : 177 satellites.
- India : 62 satellites.
- Canada : 56 satellites.
- Germany : 48 satellites.
- Luxembourg : 45 satellites.
- Argentina : 38 satellites.
- Israel : 27 satellites.

❖ *SPACE ENERGY*

Everything scientists can observe in the universe, from people to planets, is made of matter. Matter is defined as any substance that has mass and occupies space. But there's more to the universe than the matter we can see. Dark matter and dark energy are mysterious substances that affect and shape the cosmos, and scientists are still trying to figure them out. (3)

❖ *SPACE ENERGY DISTRIBUTION*

There is abundant energy in space. Even though most of deep space (the vast stretches of empty area between planets, stars and moons) is cold and dark, space is flooded constantly by electromagnetic energy. All stars in the universe produce energy and send it out into space Basically energy distribution tells us about how much energy in space is distributed by particular matter. Here, matter indicates the thing that is covering the entire dark space. Above we knew that dark matter is a theoretical concept of space. From theory we also know that dark matter consists of 69% energy of space. It only measured under the observable universe . we are still unaware about the rest matters that are in the unobservable space. (3)



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