

The Universe, Origin and its Composition

July 10, 2026 • vajiramandravi.com



The Universe is a vast endless space that includes galaxies, stars, planets, and other forms of matter and energy in it. The universe was born with the **Big Bang** as an unimaginably hot, dense point. In its early stages, the entire universe was compressed into an infinitely small point known as the singularity. Space expanded from that singularity, resulting in the visible universe that exists today.

The universe is approximately **13.787 billion years old**, according to a wide range of observations, including distant **supernovae**, the cosmic microwave background, and the abundance of **light elements**.

Origin of the Universe

The universe is approximately **13.787 billion years old**. The widely accepted theory of the origin of the universe is the "**Big Bang**" theory (expanding universe hypothesis).

The Big Bang Theory

According to this theory, the universe started with a **huge explosion**, and matter (dust and gases) filled the entire space. Matter from the universe was thrown out with great force in all directions and started expanding outwards. From this matter, many groups of stars were formed known as '**galaxies**'.

- The **Big Bang Theory** proposes the following stages in the development of the universe:
 - **Singular atom:** Initially, all matter in the universe existed in a **singular atom**, often referred to as a "**tiny ball**." This atom had an incredibly **small volume**, **infinite temperature**, and **infinite density**.
 - **Explosion:** The "tiny ball" **violently exploded**, leading to a tremendous expansion.
 - **Cooling down period:** Within approximately 300,000 years from the Big Bang, the **temperature** of the universe **dropped** to around 4,500K (Kelvin), allowing **atomic matter** to arise. This resulted in the universe becoming transparent.
 - The expansion of the universe refers to the **increase in space between galaxies**.

The Formation of Galaxies and Stars

In the early universe, the **distribution of matter and energy** was not uniform. Variations in density resulted in variations in **gravitational forces**, causing matter to be drawn together. These **density differences** served as the foundation for the formation of galaxies.

- **Galaxy:** A galaxy comprises a **multitude of stars** and spans vast distances, often measured in thousands of light-years. Individual galaxies have diameters ranging from 80,000 to 150,000 light-years.
 - **Formation:** The formation of a galaxy begins with the **accumulation of hydrogen gas** in the form of a massive cloud known as a **nebula**. Over time, these nebulae undergo growth and develop localized clumps of gas.
 - **Major forms** namely, **spiral** galaxies, **elliptical** galaxies, and **irregular** galaxies.
- **Milky Way Galaxy:** The Milky Way is the **galaxy** in which the **Solar System** is located. It's a **spiral galaxy** with a disk of stars that stretches over 100,000 light-years. Earth is situated along one of the galaxy's spiral arms, approximately halfway from the center.
 - **The Andromeda Galaxy**, also called Messier 31, is the **nearest major galaxy** to the Milky Way.
- **Stars:** These localized clumps of gas **continue to condense** and become even denser, leading to the formation of stars.
 - Star formation occurred approximately **5-6 billion years** ago.
 - This process of gas condensation and star formation played a pivotal role in shaping the **structure and composition of galaxies** as we observe them today.
- **Formation of Planets:** The development of planets is believed to occur in the following stages:
 - **Early stage:** Within a nebula, stars form as localized lumps of gas. The gravitational forces within these lumps lead to the **formation of a core** in the gas cloud. Around this core, a **vast rotating disc** of gas and dust begins to develop.
 - **Subsequent stage:** The gas cloud undergoes condensation, and the surrounding matter evolves into **small-rounded objects**.
 - Through the process of cohesion, these small-rounded objects, known as **planetesimals**, start to form. Collisions between these planetesimals and their gravitational attraction caused the material to merge and stick together.
 - **Final stage:** A large number of these planetesimals **accrete**, or come together, to form **fewer and larger bodies** known as planets.

- **Exoplanets:** An exoplanet is any planet outside of our solar system. The majority of exoplanets orbit other stars, but free-floating exoplanets, also known as **rogue planets**, are not bound to any star.

Composition of the Universe

Everything in the universe, including people and planets, is made of matter. **Matter** is defined as any substance with mass that occupies space. However, the universe is made up of more than just visible matter. The universe is **made up of three components:** normal or visible matter, dark matter, and **dark energy**.

- **Normal Matter:** Normal matter consists of the atoms that make up stars, planets, exoplanets, human beings, and every other visible object in the Universe.
 - The majority of normal matter is composed of atomic particles known as **protons, neutrons, and electrons**. It can exist as a gas, solid, liquid, or plasma of charged particles.
 - It comprises **less than 5% of the total universe**.
- **Dark matter:** Like ordinary matter, dark matter occupies space and contains mass. But it doesn't reflect, absorb, or radiate light, at least not enough to detect yet.
 - Comprises of **27%** of the universe.
- **Dark Energy:** Dark energy is another enigmatic component, comprising about **68% of the universe**. The nature of dark energy is still the subject of extensive research and speculation.
 - Since the late 1920s, astronomers have known that the universe is expanding.
- The reason for this is unknown, but the leading explanation is that the universe contains something with a **repulsive gravitational effect**, which pushes the universe apart rather than pulling it back together. This phenomenon is known as **dark energy**.
- **Black Hole:** Black holes are among the most mysterious **cosmic objects**, being extensively studied but not fully comprehended. These objects aren't holes.
 - Black holes **do not emit or reflect light**, so they are effectively invisible to telescopes.
 - Black holes are massive concentrations of matter compressed into extremely small spaces. A black hole is so dense that the **gravity** just beneath its surface, known as the **event horizon**, is so strong that nothing, including light, can escape.
- **Singularity:** Singularities were first predicated as a result of **Einstein's Theory of General Relativity**, which resulted in the **theoretical existence of black holes**.
 - The theory predicted that any star with a mass greater than a certain point would exert a gravitational force so strong that it would collapse.

The Universe - Origin and its Composition UPSC PYQs

Question 1: The terms 'Event Horizon', 'Singularity', 'String Theory', and 'Standard Model' are sometimes seen in the news in the context of **(UPSC Prelims 2017)**

1. Observation and understanding of the Universe
2. Study of the solar and the lunar eclipses
3. Placing satellites in the orbit of the Earth
4. Origin and evolution of living organisms on the Earth

Answer: (a)

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