

IS THERE AN ALTERNATIVE TO THE BIG BANG THEORY?

Nearly 14 billion years ago, there was nothing and nowhere. Then, due to a random fluctuation in a completely empty void, a **universe** exploded into existence. Something the size of a subatomic particle inflated to unimaginably huge size in a fraction of a second, driven apart by negative-pressure vacuum energy. Scientists call this theory for the origin of the universe the **Big Bang**.

WHAT IS THE UNIVERSE, ANYWAY?

What we call the “observable universe” (or the “Hubble Volume”) is the spherical region, about 90 billion light-years in diameter, that is centered on any given observer. This is the only part of the universe in which light has had time to reach the observer in the 13.8 billion years since the universe began.

EDGE OF OBSERVABLE UNIVERSE

THIS HUBBLE VOLUME IS CENTERED ON EARTH

EARTH

45 BILLION LIGHT-YEARS

Since the universe’s expansion is accelerating, objects are being dragged out of Earth’s Hubble Volume and will become undetectable to humans of the future.

THE UNIVERSE CONTINUES INFINITELY OUTSIDE EARTH’S HUBBLE VOLUME

ANOTHER HUBBLE VOLUME, CENTERED ON AN OBSERVER LOCATED OUTSIDE EARTH’S OBSERVABLE UNIVERSE.

EARTH AND THIS OBSERVER CANNOT BE SEEN FROM EACH OTHER

The Hubble Volume is more than 13.8 billion light-years in radius because the expansion of space has increased distances between objects faster than light can travel.

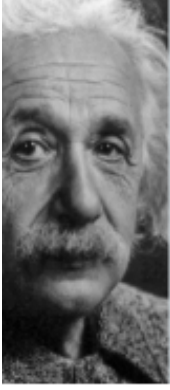
EVIDENCE FOR A BIG BANG

ABOVE: TEXTURE OF THE COSMIC MICROWAVE BACKGROUND RADIATION

Astronomers make three assumptions about the universe based on theory and observation:

- The **laws of physics are universal** and don’t change with time or location in space.
- The universe is homogeneous, or **roughly the same in every direction** (though not necessarily for all of time).
- **Humans do not observe the universe from a privileged location** such as at its very center.



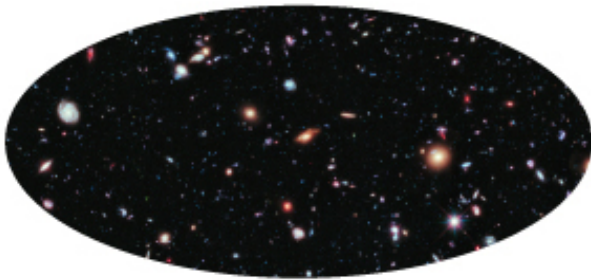


When these assumptions are applied to Einstein's equations, they indicate that the universe has these properties:

- The universe **expands** (astronomers see light from the universe's distant regions shifted toward the red end of the spectrum by the expansion of the space between).
- The universe emerged from a **hot, dense state** at some finite time in the past.
- The **lightest elements**, hydrogen and helium, were created in the first moments of time.
- A **background of microwave radiation** fills the entire universe, a relic of the phase transition that occurred when the hot, early universe cooled enough for atoms to form.

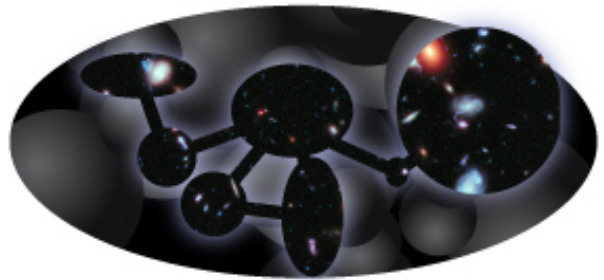
BUT "WHAT IF?"

If any of astronomers' basic assumptions are wrong, the Big Bang theory would not explain the properties of this universe. Is it possible that a Big Bang never happened?



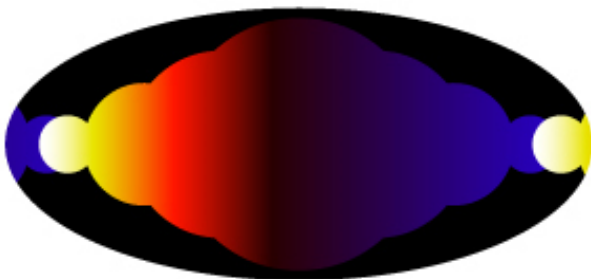
STEADY-STATE UNIVERSE

An early rival to the Big Bang theory, Steady State posits **continuous creation of matter** throughout the universe to explain its apparent expansion. This type of universe would be infinite, with no beginning or end. However, a mountain of evidence found since the mid-1960s indicates that this theory is not correct.



ETERNAL INFLATION (LEVEL II MULTIVERSE)

After the Big Bang, the universe expanded rapidly during a brief period called inflation. The Eternal Inflation theory posits that **inflation never stopped**, and has been going on for an infinite length of time. Somewhere, even now, new universes are coming into existence in a vast complex called the **multiverse**. Those many universes could have different physical laws.



OSCILLATING UNIVERSE

Originally, the **cyclic model** of the universe involved an endless series of Big Bangs, followed by Big Crunches that restarted the cycle, endlessly. The modern cyclic model involves colliding "**branes**" (a "membrane" within a higher-dimensional volume called the "bulk").



OTHER THEORIES

Implications found in quantum gravity and string theory tantalizingly suggest a universe that is in reality nothing like how it appears to human observers. It may actually be a **flat hologram** projected onto the surface of a sphere, for example. Or it could be a completely **digital simulation** running in a vast computer.

SOURCES: THE AMERICAN MUSEUM OF NATURAL HISTORY; MAX TEGMARK, "PARALLEL UNIVERSES"; NASA

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