

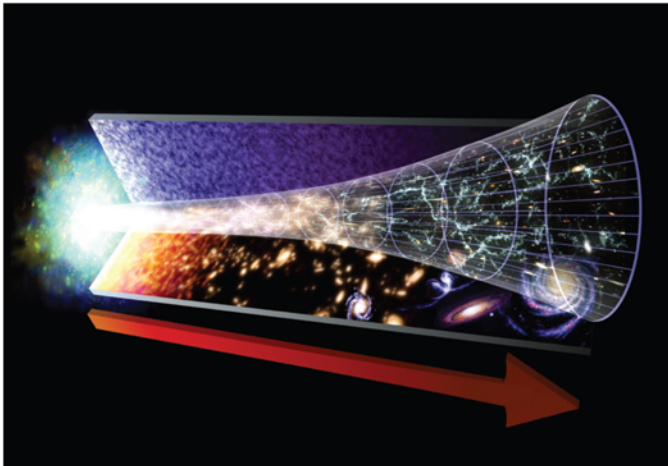
## Article: How Did the Universe Begin?

The origin of the universe is one of the deepest questions humans have pondered. Today, the leading scientific model that describes the origins of the universe is the Big Bang theory. According to the Big Bang theory, about 13.82 billion years ago, the universe was an incredibly tiny volume of space smaller than a grain of sand. This space was filled with an extremely hot, dense concentration of light that was at least one hundred million trillion trillion, or  $10^{32}$  degrees!

Immediately the early universe began to rapidly expand. The initial moment of the expansion has come to be known as the Big Bang, although there was no "bang". As the universe grew, the light became more spread out, and subatomic particles began to form. Like steam expanding out from a kettle of boiling water, the universe gradually cooled as it expanded. As it cooled, some of the particles combined to form new particles. Many of the properties of the universe that astronomers observe today have their origins in this very early period. The Big Bang theory says that the universe continues to expand today.

The Big Bang theory is an intriguing model, but it also raises many questions:

- What happened immediately after the Big Bang?
- Will the universe continue to expand forever?
- Does the universe have an edge?
- What is the evidence that supports the Big Bang theory?



*The universe has expanded and cooled since the Big Bang*

### What happened in the early universe?

The Big Bang is often described as being an explosion. However, it was different in one important way. When a balloon explodes, pieces of it fly outward into empty space that was *already present* before the explosion. According to the Big Bang theory, the *entire universe* expanded outward in all directions from a tiny point. The universe includes everything that exists, so there was no space outside of it for the universe to expand into. Instead, the particles present in the early universe spread farther and farther apart over time. This behaviour is what astronomers call "the expansion of the universe." It is challenging to understand exactly what this means, but the concepts needed to understand the universe do not always fit with our everyday intuitions.

Shortly after the Big Bang, the universe included a mix of different types of subatomic particles that were moving extremely quickly. These particles included electrons and less familiar particles such as quarks. As the universe cooled over time, the particles slowed down and combined with other particles to form larger, more complex particles.

One microsecond after the Big Bang, the universe had cooled to about 10 trillion degrees. Quarks combined to form the first protons and neutrons.

Three minutes after the Big Bang, the universe had cooled to about 1 billion degrees. Protons and neutrons combined to form hydrogen and helium, the two lightest elements in the periodic table.

Approximately 380 000 years after the Big Bang, the universe had cooled to about 3000 degrees. Particles were now moving slowly enough that electrons combined with protons and neutrons to form the first atoms in the universe.

### Will the universe continue to expand forever?

One of the main influences on the universe's expansion is gravity. Gravity is a force; any object with mass exerts gravity. Gravity causes objects to attract one another, makes matter clump together, and, on a large scale, slows the universe's expansion. With enough matter in the universe, the force of gravity would be strong enough to halt the universe's expansion and eventually cause it to contract.

Until recently, scientists did not know whether there was enough matter to make the universe contract. However, in 1998 this changed when scientists postulated the existence of a new invisible type of energy called **dark energy**. Dark energy exerts a force that causes different parts of the universe to repel each other in an anti-gravitational fashion. Astronomers now believe that the universe contains a vast quantity of dark energy spread evenly throughout it. The presence of dark energy speeds up the universe's expansion, and astronomers currently believe that the universe will continue to expand forever.

### Does the universe have an edge?

When we look at the night sky, we can see far across the universe. However, for us to see any object, light must travel from the object to us. Light does travel very fast, but it has a finite speed:  $3.0 \times 10^8$  m/s. At this speed, light could circle Earth at the equator seven times every second.

According to the Big Bang theory, the universe is approximately 13.82 billion years old. While light can travel very far during this time, it can still only cover a finite distance. This means that we cannot see any object that is farther away than the distance that light has travelled in 13.82 billion years. This places a limit on the size of what astronomers call the "observable universe." In this sense, the universe does have an edge that corresponds to the farthest we can possibly see in all directions.

But what lies beyond the observable universe? Because we cannot see anything past it, we know very little about it. Astronomers suspect that the universe goes on forever past the edge of the observable universe, but they simply do not know for sure.

### What is the evidence that supports the Big Bang theory?

Nearly 14 billion years is an incredibly long time. Yet, the Big Bang theory is a very detailed and precise model. How can astronomers be so sure that it is a good model of the early universe? How can they seem to know so much about such distant events that they cannot directly observe or perform controlled experiments on?

The Big Bang theory is currently our best theory because it predicts three important phenomena that have been observed:

1. Cosmic microwave background (CMB), a faint glow of microwave radiation that is all around us and whose properties were predicted by the Big Bang theory before the CMB was observed.
2. Relative abundances of elements in the universe. The Big Bang theory predicts that the relative amounts of hydrogen and helium are 75% hydrogen and 25% helium, the exact amounts astronomers have observed.
3. Distant galaxies are moving away from us. The farther they are from us, the faster they are travelling. This behaviour was observed by Edwin Hubble in 1929 and is exactly what the Big Bang theory predicts.

The Big Bang theory is one of the greatest triumphs of modern science. It is also the latest in a series of models of the early universe. As more observations are made, scientists always check their models and, where necessary, refine them. As astronomers continue to learn more about the universe, the Big Bang theory may eventually be replaced by an even better model.