FYI

The Formation of the Universe

Scientific theories about the formation of the universe assume that it started as an extremely hot, dense point that contained all the energy of the universe. The point was so hot and dense that matter could not exist—all of the energy was in the form of radiation. Today, a faint glow of microwave radiation, known as the **cosmic microwave background radiation (CMBR)**, fills the sky—a relic of the birth of our universe.

Time as we know it officially began when that original point began to expand. This event is often referred to as the **big bang**. It is hard to visualize the big bang because any Earth-based analogy, such as a bomb exploding or a cake rising, occurs within a surrounding environment. A bomb may explode in a room or in the air, but it is always surrounded by other objects. There was nothing surrounding the big bang—all of the matter and energy that exists was once inside that single point. Even space and time exploded into being with the big bang!

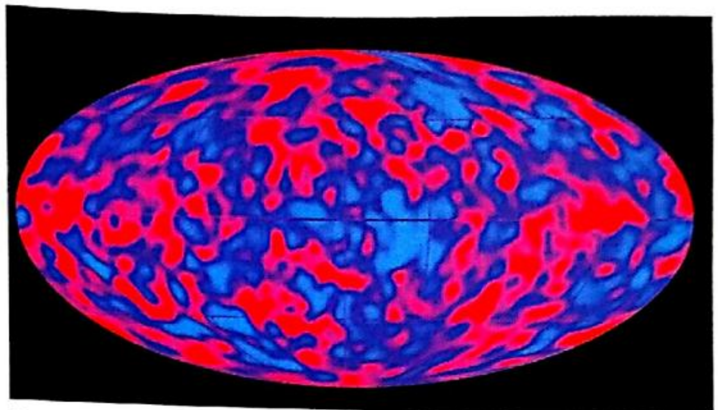

Figure 1-5: Image of cosmic microwave background radiation

The first 10^{-43} seconds after the big bang are called the **Planck Era**. There were tremendous fluctuations in energy from one point to the next, leaving the hot and dense universe in a very unstable state. This had a dramatic effect on space and time—such a peculiar and radical effect that our current understanding of physics is not able to explain what the universe would have been like in this early moment.

At 10^{-38} seconds after the big bang, the forces we now know—gravitational, electromagnetic, and nuclear forces—came into play. Scientists describe the relationship of the forces at this time with a **grand unified theory (GUT)**. During this **GUT era**, the forces were beginning to distinguish themselves from each other. In describing the universe during the times when the forces were unified, scientists have come up with constructs such as **string theory** to explain the behavior of matter and energy under this grand unified force.

It is thought that the separation of forces during the GUT era may have caused the release of a tremendous amount of energy. This energy was enough to make the universe expand exponentially from the size of an atomic nucleus to the size of our solar system in a matter of just 10^{-36} seconds. This idea is part of **inflation theory,** which is an extension of the big bang theory. During inflation, **quantum** density fluctuations in the universe were magnified to cosmic size and became the seeds for the growth of large-scale structure in the universe as we know it today. Large clumps of galaxies in some regions of the universe and large empty spaces in others are evidence that the universe must have undergone a period of rapid inflation. It is believed that large-scale structure in the universe could not have formed without this period of rapid expansion because of the homogeneous nature of the early universe.

When the universe was the ripe old age of one one-thousandth of a second (10^{-3} seconds), particles such as protons, electrons, and neutrons formed. These building blocks of atoms came from even simpler particles, such as quarks, that were generated following the GUT era. The particles that were formed in the early universe had the same properties and were governed by the same physical laws that we experience today.

When the universe was about 1 second old, the protons and neutrons began to join together to become atomic nuclei. The first elements to form were hydrogen and helium, the two lightest elements (with the lowest number of protons). Even today, hydrogen and helium are the most abundant elements in the universe, comprising nearly 99% of all matter.

Up until 400,000 years after the big bang, the temperature was still so high in the energy-rich universe that electrons were not bound to atomic nuclei. They were free-floating particles in the "cosmic soup." When the universe had expanded, and thus cooled enough, the electrons became bound to atoms, and the first neutral atoms were formed (with charge = 0). Once free electrons were no longer scattering radiation in random directions, the universe became transparent, meaning that radiation could pass unobstructed through regions of space. When this occurred, matter was able, under gravitational force, to condense into clouds without being pushed apart by radiation pressure. This eventually led to the formation of stars.

At about 1 billion years after the big bang, the universe was cool enough that galaxies were able to form. Once galaxies started forming, they did so with a vengeance. The universe soon became heavily populated with many types of galaxies.

Star formation and galaxy formation continue today, billions of years after the universe first came into being. The universe itself continues to expand and cool. Our sun formed about 4.5 to 5 billion years ago, and our Earth around the same time. The earliest life forms on Earth, microbes, have been traced back to about 4 billion years ago, and the earliest signs of human life arose only 400,000 years ago, a mere speck of time in the universe's long history.

Checking In

1. What are the two most abundant elements in the universe, and approximately how long ago did they form?
2. Explain the big bang theory of the formation of the universe in your own words and drawings.