# Big Bang Theory

(essay)

A cosmological model to explain the origins of matter, energy, space, and time, the Big Bang theory asserts that the universe began at a certain point in the distant past—current estimates put it at roughly 13.7 billion years ago—expanding from a primordial state of tremendous heat and density. The term is also used more generally to describe the vast explosion that erupted at the beginning of space and time, bringing the universe into being. First conceived by astronomers and physicists in the early twentieth century, the Big Bang was effectively confirmed in the middle and latter years of the century, once new telescopes and computers made it possible to peer further into the universe and process the enormous amounts of data those observations generated. The term “big bang” comes from its underlying hypothesis, that the universe has not been eternal but emerged out of a sudden, almost incomprehensibly vast explosion.

Scientists’ understanding of the Big Bang theory emerges out of two separate fields of inquiry: theoretical physics and observational astronomy. According to what are called the Friedmann models, a set of complex metrics named for Alexander Friedmann, an early twentieth century Soviet physicist who first developed them, the Big Bang theory fits in with two of the most important theories of twentieth century physics: the cosmological principle (which says that basic physical properties are the same throughout the universe) and Albert Einstein’s General Theory of Relativity of 1915-1916, which conceives of gravity as a curvature in space and time. That convergence of ideas, say physicists, provides the theoretical underpinning of the Big Bang theory.

Astronomers have made their own confirmations of the Big Bang theory. Analyzing the light coming from other galaxies, they have noted shorter and longer wavelengths proportional to the distances of the galaxies from Earth, indicating that they are moving away from the Earth and thus that space itself is expanding. The existence of cosmic microwave radiation, a remnant of hot ionized plasma of the early universe offers more proof of the Big Bang, as does the distribution of heavier and lighter elements through the universe.

**Timeline of the Big Bang**

The Big Bang theory hypothesizes that there were time-based stages in the origins of the universe. The first stage—or, at least, the first stage that cosmologists can theorize about given current understanding of physics—is known as the Planck era, after the German scientist of the late nineteenth and early twentieth centuries who studied the physics that explain it. The Planck era was extremely brief—just 10-43 seconds (also known as one Planck time). During this period, all four forces of the universe—gravity, electromagnetic energy, and the weak and strong nuclear forces—were theoretically equal to one another, implying that there may have been just one unified force. The Planck era was extremely unstable, with the four forces quickly evolving into their current forms, starting with gravity and then the strong nuclear force (what binds protons and neutrons together in the nucleus of an atom), the weak nuclear force (associated with radioactive decay, it is some 100 times weaker than the strong force), and finally electromagnetic energy. This process is known as symmetry breaking and led to a longer period in the universe’s history--though, at one millionth of a second, still extremely brief in ordinary time--known as the “inflation era.” Physicists, however, are not certain of the energy force that led to this inflation. At one second in age, the universe now consisted of fundamental energy and sub-atomic particles such as quarks, electrons, photons, and other less familiar particles.

The next stage in the Big Bang—lasting for roughly 100,000 years and beginning about three seconds after the Planck era—consisted of the process of nucleosynthesis, as protons and neutrons came into being and began to the form the nuclei of various elements, predominantly hydrogen and helium, the two lightest elements in the periodic table and the two most common elements in the universe. Yet matter as we know it still did not exist and for those hundred thousand or so years, the universe essentially consisted of radiation in the form of light, radio waves, and X-rays. This period, known as the “radiation era,” came to a gradual end as free floating atomic nuclei bonded with free-floating electrons to produce the matter with which the universe would subsequently consist. While time was critical to the process so was temperature and density, with the various changes corresponding to a gradual cooling of the universe and the gradual dispersing of matter.

It took some 200 million years for gravity to begin coalescing these free-floating atoms into the primordial gas out of which the first stars and galaxies would emerge. Over billions of years, such early stars and galaxies phased through their lifecycle, using up their nuclear fuel and collapsing in on themselves, spewing out vast new clouds of matter and energy that would eventually form new generations of stars and galaxies. The sun around which the earth and the solar system rotate is one of these later generation stars, formed roughly five billion years ago.

# Fate of the Universe

The Big Bang theory concerns not just the origins of the universe but its ultimate fate. The critical question, of course, is whether the universe will continue expanding forever or eventually fall back into itself, creating, perhaps, the conditions for the next Big Bang. Gravity is the critical factor here, with three outcomes possible. The first, and most widely accepted by physicists, is that there is not the critical density, known as omega and estimated at roughly six hydrogen atoms per cubic meter, necessary to pull the universe back in on itself. In this model, referred to as the “open” model, the universe will continue to expand and cool indefinitely. If however, the density of he universe is greater than omega then the universe will eventually, after billions of years, collapse in what physicists call the “big crunch.” A third and highly unlikely possibility is that omega equals precisely one; in this model, the universe gradually slows and cools to a static state.

While it would seem at first glance that the fate of the universe—that is, whether matter exceeded omega or not--could be determined by the admittedly complex but not impossible task of calculating the amount of matter and dividing it by the dimensions of the universe, in fact, there is a complicating factor. The galaxies and nebulae, or primordial dust clouds out of which stars and galaxies, do not pull on themselves or on each another as they should. That is to say, they behave as if there was more mass and, hence, gravitational pull than can be observed. For example, the Andromeda galaxy, the nearest neighbor to our own Milky Way galaxy, is rushing toward us at 200,000 miles per hour, a speed that cannot be explained by the gravitational force of the matter in the two galaxies. In fact, the two galaxies are coming together at a pace requiring some 10 times that amount of matter. Physicists offer the possibility that there is dark matter in the universe, that is, an unknown type of matter that does not emit or reflect enough electromagnetic energy to be observable by current means. Such dark matter, according to this hypothesis, exists in haloes around galaxies and may be what composes black holes and massive clouds of neutrinos, particles formed from radioactive decay with little mass and no electric charge. Such dark matter would imply a universe that eventually collapses in on itself, except for an additional complicating factor.

Scientists hypothesize that there is also a dark energy in the universe counteracting both matter and dark matter, a kind of anti-gravitational force that is also undetectable with existing technology. While dark matter is believed to constitute 22 percent of the universe, dark energy is believe to compose 74 percent. These numbers, along with the difficulties of detecting dark matter and energy make it impossible for physicists as of the early twenty-first century to come to a definitive conclusion about the ultimate fate of the universe.

# Pre-Twentieth Century Ideas of Universe’s Origins

The origins of creation have, of course, preoccupied humanity since at least the beginning of civilization itself. Virtually every culture around the world has created myths to explain how the universe came into being, even if they did not necessarily comprehend the universe’s magnitude and complexity. These cosmologies, or explanations for the existence of creation, generally share four basic ideas. First, there is an intelligence or creator behind creation. Second, the universe came into being at a specific point in time and that what existed before the universe came into being is irrelevant as there was no existence or time before it. A major exception to this model of a universe created at a single moment in time comes from Hindu cosmology which states that the universe exists in cycles, of roughly 4.5 billion years, or one day in the life of the Brahma, the creator, endlessly being born, dying, and being reborn. The third component of most ancient cosmologies was that the Earth stood at the center of creation.

And the final element was that, once the universe was created, it remained essentially static--nothing added, nothing taken away, all matter and energy in perpetual balance. That, too, was the model advanced by English scientist Isaac Newton in the late seventeenth and early eighteenth centuries, whose understanding of the laws of the universe dominated physics for more than 200 years. But even in Newton’s own time, the idea of a perpetually balanced creation was questioned by some thinkers, who pointed out that the universe would come apart if just one object should slip out of balance. And while Newton’s laws attempted to explain how the universe operated, they did not offer much insight into its origins.

Immanuel Kant, a German philosopher of the late eighteenth century, was the first major Western thinker to tackle the question that the Big Bang theory would eventually answer—had the universe always existed or did it come into existence at a specific point in time? Kant concluded that since both arguments were equally valid on the face of things and that it was impossible to determine which was fundamentally true, the question of the universe’s origins, or lack thereof, was beyond human comprehension. Even as nineteenth century astronomers began to push back the envelope of what was known about the universe’s scale, they did not have the means or, given their religious faith, the inclination to grapple with Kant’s question.

**Early Hypotheses**

Early twentieth century physicists and astronomers, of course, would prove Kant wrong. In 1912, an American astronomer named Vesto Slipher noted a Doppler shift in the wavelengths of light coming from spiral nebulae, an antiquated term for galaxies, dating from before the existence of other galaxies was confirmed. (It was American astronomer Edwin Hubble who first concluded in the mid-1920s that the nebulae were, in fact, galaxies similar to our own Milky Way.) The Doppler shift, named after Christian Doppler, the early nineteenth century Austrian mathematician who discovered it, says that waves alter in relation to the movement of the observer or the object causing the wave. While Slipher noted that almost all such spiral nebulae were moving away from the Earth, he failed to reach the conclusion that this meant the universe was expanding.

Around the same time, Slipher was making his observations, Friedmann, the Soviet physicist, explained how Einstein’s General Relativity Theory might prove that the universe was expanding. Einstein’s theory updated and revised Newton’s gravitational laws, for conditions where enormous mass and energy existed. Newton concluded that gravity was a force between two masses; Einstein argued, correctly as it was proved by later experiments, that gravity was the warping of space and time caused by mass. While Newton’s model of gravity was not consistent with the Big Bang theory—since there was no mass in the primordial state of heat and density at the beginning of time—Einstein’s allowed for the possibility of gravity itself coming into being, though, ironically, Einstein himself held to a static view of the universe when he came up with his General Relativity Theory.

Roughly a decade after Friedmann developed his models out of Einstein’s General Relativity Theory—models that, while published, generally got overlooked by other physicists--a Belgian physicist and astronomer Georges Lemaître, independently coming up with the same theories as Friedmann, used them to reach the conclusion that had eluded Slipher—that receding nebulae meant the universe was expanding. In 1931, Lemaître also hypothesized that the universe must have begun with a single atom, an idea that came to be called the “cosmic egg” theory. American astronomer Edwin Hubble, the first to realize that nebulae were in fact other galaxies, also confirmed that the galaxies all seemed to be moving away from us simultaneously. Extrapolating backward, Hubble believed that they all had emerged from the same high-density place, exploding outward in a kind of initial fireball. Hubble made his findings by noting shifts in the light spectrum of distant galaxies that fit in with the Doppler effect.

Despite such findings, a competing theory emerged in the years after World War II,. The “steady state” model, advocated by British astronomer Frederick Hoyle, held that new matter was created as the universe expanded. A confirmed atheist, Hoyle rejected the “cosmic egg” theory as it seemed to imply the existence of a creator. Ironically, it was Hoyle who, in the 1950s, coined the term “Big Bang,” using it in a radio interview to ridicule Lemaître’s ideas. To reconcile his constant universe idea and the observed fact that galaxies were moving away from each other, Hoyle hypothesized that new galaxies came into being as older ones grew apart. While later discounted, Hoyle’s work was useful in explaining how matter and energy came into existence, a key component of the Big Bang theory.

# Confirmation of the Big Bang Theory

For two decades the two theories vied with each other, though Lemaître’s steadily gained more advocates. The critical confirmation of the Big Bang theory came in 1964. That year, Arno Penzias and Robert Wilson, two scientists working for Bell Laboratories, noticed that background microwave radiation, a residual form of energy from the Big Bang, permeated the universe, confirming an idea first propounded by Soviet physicist George Gamow and American physicist Ralph Alpher in the late 1940s.

With the development of ever more powerful computers to crunch the numbers in the 1980s, and the deployment of the Hubble Space telescope in the 1990s, which allowed for observations above the distortions of the Earth’s atmosphere and radio waves, astronomers were able to make ever more detailed pictures of the universe and ever more precise timelines for the Big Bang. Key to this was a worldwide study in the 1980s and 1990s of supernovas, immense outpourings of radiation caused by the collapse of massive stars, which pointed to yet another anomaly about the universe. Rather than expanding at a constant rate, it seemed to be accelerating. This led to the conclusion that there must be a dark energy in the universe working to counteract gravity. One recent hypothesis states that space actually consists of negative pressure, which grows as the universe expands thereby causing that expansion to accelerate since there is not enough matter—even with dark matter factored into the equation--to put a brake on the expansion. According to British scientist Robert Caldwell, this accelerating expansion may lead to what he calls the “big rip,” in which galaxies, stars, and even atoms are eventually torn apart by the force of dark energy, leading to the destruction of matter in the final seconds of time at the end of the universe. Much of this work on dark matter and energy remains hypothetical, of course, as it has been impossible to detect either of these two phenomena.

As the twenty-first century dawns, scientists—like the ancients long before them--are still grappling with the very moment of creation, before the radiation, inflation, and Planck eras. Many believe that unveiling that moment is connected to the development of a Grand Unified Theory, a single explanation that fits all of the known laws of the universe—including Einstein’s General Relativity Theory and quantum mechanics, the study of energy and matter at the sub-atomic level—into a single equation. As British physicist Stephen Hawking notes, "At the Big Bang, the universe and time itself came into existence, so that this is the first cause. If we could understand the Big Bang, we would know why the universe is the way it is. It used to be thought that it was impossible to apply the laws of science to the beginning of the universe, and indeed that it was sacrilegious to try. But recent developments in unifying the two pillars of twentieth-century science, Einstein's General Theory of Relativity and the Quantum Theory, have encouraged us to believe that it may be possible to find laws that hold even at the creation of the universe."

**References**

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