What Is the Big Bang?

Should Christians Believe It?

By J. Gilbert Miller, PhD

In his book *The Structure of Scientific Revolutions*, Thomas Kuhn discusses paradigm shifts that occur when an older paradigm that has experienced a crisis in explaining certain phenomena is replaced by a new one that addresses the anomalies of the older paradigm.[1] Kuhn argues that the transfer of allegiance from one paradigm to another is not based on proof or validation of the new paradigm, but on a conversion experience that cannot be forced. This conversion process takes many years (decades and even centuries) to happen. It is usually the younger scientists who embrace the new paradigm more enthusiastically, often based on esthetics (for example, the new paradigm is simpler or is based on a more beautiful theory) rather than on strict proof. The old-guard scientists often never embrace the new paradigm, which becomes universally accepted in the scientific community when the old-guard dies off. A famous example is Einstein's unwillingness to accept quantum mechanics and his remark that "God does not play dice."

The Ptolemaic system, developed by the Greek astronomer Ptolemy, provided a cosmological paradigm that endured for centuries. It was a geocentric cosmology, with the motion of the planets described by two circles, one called the deferent and the other the epicycle. This complicated system was devised to explain the retrograde motion of the planets. The other celestial bodies (Sun, Moon, and stars) moved on the celestial sphere around the fixed Earth. As more precise planetary observations were made with the invention of the telescope, a crisis developed with the Ptolemaic model. Constant revisions of the deferent and epicycle circles had to be made to fit the data. Copernicus suggested that a heliocentric model better fit the observations, but the claim was not readily accepted because the improvement was only marginally better than the Ptolemaic system. The Copernican model was not widely accepted

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[1] Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 50th Anniversary Edition (1962; repr., Chicago: University of Chicago Press, 2012).

until Kepler discovered his three laws of planetary motion. From the planetary observations of Danish astronomer Tycho Brahe, Kepler discovered the following:

1) the orbit of each planet is an ellipse, with the Sun at a focus,
2) the line joining the planet to the Sun sweeps out equal areas in equal times, and
3) the square of the period of a planet's orbit is proportional to the cube of its mean distance from the Sun.

It is important to note that Kepler's laws are descriptive in nature and were derived by induction, not by deduction from some new theory. For example, Kepler's first law does not explain why the planetary orbits are ellipses. The change in paradigm to the Copernican model has been called the Copernican Revolution because of the radical change in the cosmological model.

The church, both Catholic and Protestant, opposed the Copernican theory of the Earth orbiting around the Sun, believing that the Holy Scriptures supported a geocentric cosmology. For example, the verse "He set the earth on its foundations, so that it should never be moved" was used to support a fixed Earth (Psalm 104:5 ESV).[2] Also, the verse "'Sun, stand still at Gibeon, and moon, in the Valley of Aijalon,' and the sun stood still, and the moon stopped, until the nation took vengeance on their enemies" was used to support the idea that ordinarily the Sun and Moon moved and not the Earth (Joshua 10:12–13 ESV). The church viewed the Copernican theory as a challenge to the authority of Scripture and considered Copernicus to be a heretic. The Catholic Church banned Copernicus's publication *De Revolutionibus Orbium Coelestium* and later put Galileo under house arrest until his death in 1642 because of his satire in *Dialogue Concerning the Two Chief World Systems* of those who held to the Ptolemaic theory. Today however, no Christian would oppose the Copernican theory based on biblical principles. What has changed? The influence of natural revelation has caused the church to realize that its interpretation was in error, not that Scripture was in conflict with the Copernican theory. The genre of Psalm 104 is poetical, and it is a basic hermeneutical error to take verse five out of context and assume it is making a scientific statement. Likewise, even today we refer to the Sun as rising and setting from our perspective on Earth, even though we know it is due to the Earth rotating on it axis.

To understand just how firmly natural law has established the validity of the Copernican theory over the Ptolemaic theory, we need to turn to Isaac Newton. He discovered the universal law of gravity, which states that the gravitational force between two mases is inversely proportional to the square of the distance between the two masses and proportional to the product of the masses. From this simple law, one can deduce or derive all three of Kepler's laws. Everything about gravity can be derived from first principles from this one simple law. It is universal because it applies to all masses. It explains things like the perihelion precession of Mercury's orbit due to the gravitational perturbations of the other planets, and the complicated motion of the Moon from the gravitational attraction of both the Sun and the Earth (the so-called three-body problem). The application of Newton's law of gravity to the field of celestial mechanics (the motion of all heavenly bodies, both natural and man-made) has been a major triumph of science and has established Newton as a genius par excellence. Newton's law of gravity was used to predict the return of Halley 's Comet and is used today for the planetary exploration of the solar system by artificial satellites.

Newton had to invent the mathematics called calculus in order to solve for the planetary orbits using his universal law of gravity. The German mathematician and philosopher Gottfried Wilhelm Leibnitz was a coinventor of calculus. Newton used quantities called fluxions to calculate things like instantaneous velocity. Leibnitz called these quantities infinitesimals. Bishop Berkeley criticized fluxions in his book *The Analyst: a Discourse addressed to an Infidel Mathematician* saying,

> And what are these Fluxions? . . . They are neither finite Quantities nor Quantities infinitely small, nor yet nothing. May we not call them the ghosts of departed quantities?[3]

In other words, a fluxion or infinitesimal defies logic. It is a quantity that is supposed to be infinitely small and yet not zero. How small does it have to be before it is considered infinitely small? There is no answer. Such quantities do not exist. In spite of the lack of a rigorous logical

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[3] George Berkeley, *The Analyst: A Discourse Addressed to an Infidel Mathematician* (1734), https://en.wikisource.org/wiki/The_Analyst:_a_Discourse_addressed_to_an_Infidel_Mathematician.

foundation for calculus, Newton was able to use it to derive the planetary orbits from his law of universal gravity. In other words, his calculus worked. It was a century later that the German mathematician Karl Weierstrass and others provided a firm logical foundation for calculus. In modern rigorous texts on calculus, one finds no need for fluxions or infinitesimals. However, in less rigorous texts, one may still find the concept of an infinitesimal as an intuitive concept. The concept of an infinitesimal still has some use in explaining calculus in an intuitive, nontechnical way to nonmathematicians.

As more powerful telescopes were invented, another paradigm shift took place with regard to the size of the universe. The Sun is approximately 1.5×10^8 km from the Earth. The speed of light is approximately 3.0×10^5 km/sec. The time it takes light to travel from the Sun to the Earth is the distance divided by the speed of light, which equals five hundred seconds or approximately eight minutes. This means that the light from the Sun that we see on Earth at any instant left the Sun approximately eight minutes ago. The closest star to the Earth (other than the Sun) is Alpha Centauri, which is actually a binary star system, and is 4.37 light years from the Earth, and can be seen by the naked eye. This means that the light we see from this star system each night left Alpha Centauri 4.37 years ago. Currently, we are not observing this star as it exists today, but rather as it existed 4.37 years ago.

The Milky Way Galaxy is a spiral galaxy with multiple arms containing billions of stars. The Sun is located in the outer region of one of the arms. For a long time astronomers thought that all the stars in the universe were located in the Milky Way. In the twentieth century, the astronomer Edwin Hubble showed that there are many other galaxies of various shapes using the powerful hundred-inch telescope on Mount Wilson in Southern California. The closest spiral galaxy to the Milky Way is the Andromeda Galaxy, which is 2.5 million light years from the Earth. Currently, we are not observing this galaxy with the aid of telescopes as it exists today, but rather as it existed 2.5 million years ago. The most distant objects in the universe are quasars, which are billions of light years from Earth. When astronomers observe quasars, they are looking back in time to the very beginning of the universe. For this reason, verses 4–5 in Psalm 8—"When I look at your heavens, the work of your fingers, the moon and the stars, which you have set in place, what is man that you are mindful of him, and the son of man that you care for him?"—are even more significant for us today than when David penned these words (ESV).

As Kuhn points out, each new paradigm will answer questions that the older paradigm could not answer, but there will be a new set of questions that the new paradigm cannot answer as well. Eventually, there will even be anomalies that the new paradigm cannot explain. Several new questions arose from Newton's law of gravity. For example, why does one have to postulate a preferred inertial reference frame in which to express the equation of the gravitational attraction between two masses? How does the gravitational force of the Sun extend out to the infinite reaches of space? No matter how far away from the Sun a mass is, it will experience some force on it, albeit small, due to the gravitational field of the Sun. This question even bothered Newton, because there is no explanation for how the Sun could exert a force over such large distances. As more accurate measurements of the position of the planets were made, astronomers found an anomaly in the rate of the perihelion precession of Mercury based on Newton's law of gravity. There was a discrepancy between what astronomers measured and what Newton's theory predicted.

The question of a preferred reference frame bothered Albert Einstein. In 1905 he published a paper on the theory of special relativity, in which he postulated that there are no preferred inertial reference frames and that the speed of light is constant in all inertial reference frames. Any two inertial reference frames are related to each other by a Lorentz transformation, named after the Dutch physicist Hendrick Antoon Lorentz. Lorentz had arrived at his transformation in an attempt to explain the negative result of the Michelson-Morley experiment, which showed that light does not propagate in some ether that would cause its speed to be different in different reference frames. However, Einstein explained that the Lorentz transformation was a result of the postulate that the speed of light is constant in all inertial reference frames. The name "relativity" was given to the theory by Einstein because of the postulate that there are no preferred inertial reference frames and that they are all related to each other by Lorentz transformations. Many strange paradoxes arose from Einstein's theory of special relativity, like the famous twin paradox, but all of them have satisfactory explanations. Einstein's theory of special relativity gave a theoretical explanation to the results of the Michelson-Morley experiment. Also, the famous equation

$$E = mc^2$$

is derived from the theory of special relativity. It was the German mathematician Hermann Minkowski who recast the theory of special relativity in a four-dimensional space-time formulation, which would become essential for Einstein's discovery of the theory of general relativity.

In 1915 Einstein published a paper on the theory of general relativity, which extended the theory of special relativity to include gravity. More than a half century before Einstein, the German mathematician Bernhard Riemann had invented higher dimensional non-Euclidean geometry. This was just the mathematics that Einstein needed in order to formulate his theory of general relativity, which described gravity as a curved four-dimensional Riemannian (or Lorentzian) geometry, or space-time. The metric describing this geometry satisfies Einstein's field equations of general relativity, which state that mass or energy causes space-time to have curvature given by a four-dimensional Riemannian geometry. According to Einstein, gravity is a fictitious force because objects are really in free fall in curved space-time rather than being accelerated due to a force acting at a distance. This answers the objection to Newton's law of gravity, in which a massive object like the Sun exerts a gravitational force on objects at large distances from the Sun. According to general relativity, an object senses the local curved space-time and moves along the unique trajectory that experiences no acceleration or force (called a geodesic in Riemannian geometry).

The theory of general relativity predicted that light from a star that grazed the surface of the Sun would be bent by the curvature of the gravitational field near the Sun. The theory of general relativity predicted that the angle of this deflection of light by the Sun would be twice that predicted by Newton's law of gravity. Sir Arthur Eddington led a British expedition to measure this deflection during the solar eclipse on May 19, 1919. The result confirmed Einstein's theory of general relativity, and the publication of this expedition led to Einstein's popular fame. Einstein is the only physicist who has been honored by a ticker tape parade in New York City.

In addition, in 1915 Karl Schwarzschild solved Einstein's field equations for the gravitation field (Riemannian geometry) of the Sun. Mercury's orbit around the Sun could then be calculated according to the theory of general relativity, and the solution turned out to be an ellipse with a perihelion precession exactly equal to the anomaly that Newton's theory of gravity could not explain. The Schwarzschild solution also applies to stars and predicts that massive stars would collapse to form black holes. Many black holes have since been discovered in the universe, particularly at the center of galaxies.

In spite of the early verification of Einstein's theory of relativity, the scientific community was slow to accept the strange new ideas of relativity and the new paradigm that departed from time-honored Newtonian mechanics. Einstein was awarded a Nobel Prize in physics in 1922, not for his work on relativity but for his work on the photoelectric effect. Nevertheless, today Einstein is most well-known for his work on the theory of relativity.

The theory of general relativity was successful in explaining the effects of gravity locally in our own solar system, but the theory also applies to the whole universe. The cosmological principle says that on the large scale the universe is homogeneous and isotropic. This principle is an approximation and certainly is not true locally where there are irregularities (nonhomogeneity) and preferred directions (nonisotropic). However, with the cosmological principle as an assumption, in 1922 the Russian mathematician Alexander Friedmann solved Einstein's field equations for three different models of the universe. One model had positive spatial curvature, one had negative spatial curvature, and one had zero spatial curvature. All three solutions describe an expanding universe. The one with positive spatial curvature had the spatial geometry of a three-dimensional sphere with finite volume, and its expansion would reach a maximum size and then begin contracting. This model is called closed because the positive curvature causes the universe to be closed back on itself with a finite volume. The one with negative spatial curvature had the spatial geometry of a three-dimensional hyperboloid with infinite volume and would continue to expand forever. This model is called open because the negative spatial curvature causes the universe to have an infinite spatial extent (even at the very beginning!). The critical solution in between these two solutions is the universe having zero spatial curvature and infinite volume (even at the very beginning!), and it would also expand forever. This model is called flat because the spatial curvature is zero. In 1927 Belgian priest and astronomer Georges Lemaître independently solved Einstein's field equations for an expanding universe. The Friedmann-Lemaître models are called the standard Big Bang cosmological models.

At first Einstein did not accept the idea of an expanding universe and modified his field equations by adding a term, the Greek letter Λ called the cosmological constant, to counteract the expansion and give a static solution. But in 1929 Hubble showed that the Friedmann and Lemaître models of an expanding universe were consistent with his measurements of the redshifts of all distant galaxies. Like the Doppler shift of sound from moving objects, the redshift of the light from distant galaxies indicates that they are all moving away from observers on Earth. Hubble found that the speed of a receding galaxy from the Earth was proportional to the distance from the Earth. This became known as Hubble's law. Einstein later called the introduction of the cosmological constant into his field equations the "greatest blunder of my life." In the end, the fact that his original equations could predict an expanding universe and be confirmed by astronomical measurements turned out to be the highest achievement of Einstein's theory of general relativity.

It is difficult for the person not trained in higher mathematics to comprehend these cosmological models. If all the distant galaxies in the universe are receding from an observer on Earth, one might conclude that the Earth is at the center of the universe. The expanding universe model is not like an explosion where fragments all separate from one another into empty space and there is a center point of the explosion. Rather, it is a mathematical model where the very fabric of space itself is expanding (and contracting) in size. An analogy may be helpful. A balloon is a two-dimensional sphere, one dimension lower than the spatial geometry of the closed cosmological model. Mark the balloon with dots with a black pen to represent galaxies. As one blows up the balloon, the dots all separate from each other. From an observer at any one of the dots, all the neighboring dots appear to be receding from him. As the balloon deflates, an observer at any one of the dots sees all the neighboring dots approaching him. It is impossible to visualize a three-dimensional sphere expanding and contracting, but mathematicians have no problem writing equations for these higher dimensional geometries. Note that a balloon has no center. That is, the rubber surface has no center. All points on the balloon are like any other point. That is the property of homogeneity. Likewise, the closed model of the universe, which is spatially a three-dimensional sphere, has no center.

A two-dimensional hyperboloid, or saddle surface, provides a visual analogy for the open cosmological model. Imagine a rubber saddle that curves downward forever where one's legs would be and curves upward forever where the horn would be and where the horse's rear would be. Mark this infinite saddle with dots. Now, stretch the saddle in all directions uniformly. From an observer at any one of the dots, all other neighboring dots appear to be receding from him. Where is the center of the saddle surface? There is none. This surface is also homogeneous, like the two-dimensional sphere. A two-dimensional Euclidean plane provides a visual analogy for the flat cosmological model. The expansion of the flat model is analogous to the plane being made of rubber and being stretched in all directions uniformly. There is obviously no center point on a plane. So the term *Big Bang* can mislead one into thinking that there is a center point of the universe's origin. There is none. Also, the term *expanding universe* can mislead one into thinking the universe was very small at the beginning, and has been expanding for a long time to its present enormous size. That is only true for the closed cosmological model. The open and flat cosmological models have infinite spatial volume from the beginning. A more accurate term would be *stretching universe* models, where the very fabric of space is being stretched over time so that every point is receding from every other point.

There is a connection here between Kepler/Newton and Hubble/Einstein. Hubble's law is descriptive and is derived by induction based on observations, just like Kepler's laws. Hubble's law does not explain why all the distant galaxies are receding from an observer on Earth. The reason for Hubble's law is that Einstein's theory of general relativity applies to gravity on the cosmological scale and it predicts an expanding universe, just as Newton's law of gravity predicts the motion of the planets with great accuracy (except for the precession of the perihelion of Mercury). Hubble's law can be derived by deduction from the theory of general relativity. More than that, the models of Friedmann and Lemaitre can be extrapolated backward in time to a beginning approximately 13.77 billion years ago. This is how one arrives at an estimate of the age of the universe.

Wanting to avoid a beginning of the universe a finite time ago as predicted by general relativity and the expanding universe models, Fred Hoyle, Thomas Gold, and Hermann Bondi came up with an alternative cosmology, called the steady state model, which has an infinite past and infinite future. The steady model also hypothesized a continuous creation of matter in the universe. Their belief in naturalism, that everything is a result of natural causes, is what motivated the steady state model of the universe. As more astronomical observations have been made, particularly the discovery of quasars, the steady state model has been abandoned. The discovery of the cosmic microwave background radiation (CMBR) by Penzias and Wilson in

1965 put the nail on the coffin of the steady state theory. CMBR supports the Big Bang model and not the steady state model. Penzias and Wilson were awarded the Nobel Prize for physics in 1978 for their discovery of CMBR. Regardless of the failure of the steady state model, it was Fred Hoyle who gave the name Big Bang to the expanding universe models of general relativity, and although it can lead to some misinterpretations, the name stuck.

All is not perfect with the theory of general relativity. There are troublesome singularities, places where mathematical quantities become infinite. The geometry is not defined at the singularity but only arbitrarily close to the singularity. It is similar to division by zero not being defined in arithmetic, but division by an arbitrarily small number can result in an arbitrarily large number. The curvature of space-time becomes infinite at the center of a black hole and at the beginning of the Friedmann and Lemaitre cosmological models. Even the four-dimensional space-time curvature of the flat model is infinite at the beginning. (It is only the three-dimensional spatial time “slice” of the four-dimensional space-time that has zero curvature and is Euclidean.) The density of matter and energy, which causes the four-dimensional geometry to have curvature, also becomes infinite at the singularity. This is because the three-dimensional spatial geometry of all three standard Big Bang cosmological models is infinitely compressed at the singularity. Any two points become arbitrarily close to each other as measured by the distance function in the four-dimensional Riemannian geometry as the singularity is approached. For the closed model, the spatial volume approaches zero as the singularity is approached, but for the open and flat models, the spatial volume is always infinite no matter how close time approaches the singularity. So for the open and flat models, it is misleading to think that near the beginning of the Big Bang space was small. It was not small at all. It was infinite. Roger Penrose and Stephen Hawking proved the famous singularity theorem of general relativity, which states that even without the assumption of the cosmological principle all cosmological models satisfying Einstein’s field equations have singularities at the beginning of the universe. The general theory of relativity essentially breaks down at the very beginning of the universe and at the center of black holes.

Singularities have arisen before in physics. According to classical physics, the power emitted at the ultraviolet end of the spectrum by a black body in thermal equilibrium is infinite. This has been called the ultraviolet catastrophe. Max Planck introduced the idea that radiation is emitted and absorbed in discrete packets of energy, called quanta. With this idea Planck derived the correct spectrum of black body radiation, and it did not have the singularity at the ultraviolet end of the spectrum. Einstein attributed these mathematical quanta of energy to real particles, now called photons.

It is the hope of many cosmologists that a quantum theory of gravity will overcome the singularities of general relativity. Although general relativity seems quite modern, it is actually a classical theory along the lines of Newtonian mechanics and the equations of classical electromagnetism. These theories are all deterministic in that the solutions of these equations that describe the future state of some physical quantity are determined by initial conditions. This can be illustrated with a simple example of tossing a coin. Chance or probability is ascribed to events for which there is a lack of information. One says that the chance of a coin landing on heads is 50/50 or has probability one-half. But the problem of flipping a coin is deterministic. The process obeys Newtonian mechanics. If we knew the orientation of the coin in the person's hand, the force applied by the flip, the height of his hand above the ground, the speed and direction of the wind, then Newtonian mechanics could predict with absolute certainty how the coin would land on the ground. In other words, the outcome is determined by the initial conditions. Because it is difficult to know the initial conditions before the flip, we ascribe chance or probabilities to the outcome.

Quantum theory was developed by Planck, Schrödinger, Bohr, Heisenberg, Dirac and others in the early twentieth century, and it is an indeterminate theory. Schrödinger developed the wave equation of quantum mechanics. The wave function of quantum mechanics only provides probabilities of measured outcomes, not certainty of outcomes. Such ideas seem strange. Another paradigm shift must be made into the quantum realm.

Coulomb's law from classical electromagnetism is similar to Newton's universal law of gravity. Both are inverse square laws. However, the charge can be positive or negative, and the force between the two particles is repulsive for like charges and attractive for opposite charges. Coulomb's law can be used to solve for the orbit of the electron in the hydrogen atom, where the nucleus is a single proton. Since the charge of the proton is positive and the charge of the electron is negative, the force is attractive. The same mathematics (calculus) that Newton used to solve for the orbits of the planets can be used to solve for the orbit of the electron in the hydrogen atom, and the solutions are the same, that is, elliptical orbits (with a circle being a special case of an ellipse with zero eccentricity).

A planetary orbit has a total energy given by the sum of its kinetic energy and potential energy. For an orbit bounded by the gravitational attraction of the Sun, the potential energy is negative and larger than the positive kinetic energy, so that the total energy is negative. Because the inverse square law is a conservative force, the energy of a planetary orbit is constant, called a constant of motion. The values of total energy of the possible theoretical solutions of planetary orbits are all negative real numbers or a continuum of possible values. The same is true for the values of total energy for the orbit of the electron in the hydrogen atom, according to Coulomb's law.

However, the energy levels of the electron were discovered to have discrete, or quantized values by experiments conducted in the early twentieth century, before quantum mechanics was developed. Not every value in the continuum of values was possible for the total energy. The energy of the electron bound in an atom to a nucleus was never found to have an intermediate value between the discrete or quantized possible values. Why is this? The reason is that the electron is not described by classical physics and does not obey Coulomb's law, but rather is described by quantum mechanics and obeys Schrödinger's equation. To state it technically, the wave functions that are solutions to Schrödinger's equations are eigenvectors of the total energy operator and have quantized eigenvalues (the values of total energy). These quantized eigenvalues are what are measured experimentally. Moreover, the wave function provides a probability density function of where the electron might be. Its position is not determined from classical physics, where knowledge of the position and velocity at any instant of time determines where the object will be in its orbit at any time in the future. The deterministic nature of classical physics is why we are able to predict the future positions of planets, moons, comets, and other celestial objects with great accuracy.

One often sees pictures of atoms in elementary science books with electron orbits around the nucleus of the atom. This is a picture from the paradigm of classical physics and is incorrect. The problem is that quantum mechanics does not give us a very good picture to draw because it is based on abstract higher mathematics. Even descriptions of quantum theory by professional scientists often mix paradigms of classical and quantum physics. This often leads to confusion. For example, Timothy Ferris, in his book *Coming of Age in the Milky Way,* states:

> The more closely physicists examined the subatomic world, the larger indeterminacy loomed. When a photon strikes an atom, boosting an electron into a higher *orbit*, the electron *moves from the lower to the upper orbit instantaneously, without having traversed the intervening space*. The *orbital radii* themselves are quantized, and **the electron simply ceases to exist at one point, simultaneously appearing at another**. This is the famously confounding "quantum *leap.*"[4]

The italics have been added to indicate language used from the paradigm of classical physics to express quantum mechanical concepts. It would be much better to stick to words that represent concepts from the paradigm of quantum theory and avoid the loaded words from classical physics like orbit, move, traverse, radii, and leap. The electron is not a small ball of negative electric charge moving in an orbit around a more massive ball of positive charge, called a proton, at a quantized orbital radius that can leap from one quantized radius to another. What is quantized is the energy of the electron, not the radius of the orbit, and each energy level is associated with a quantum state, which is a wave function satisfying Schrödinger's equation. Even the concept of moving in an orbit is a classical construct that has dubious meaning in quantum theory. One should just say that the electron is represented by a quantum state, which is a wave function belonging to Hilbert space, an infinite-dimensional vector space with an inner product, named after the German mathematician David Hilbert. It would be better to say that the electron transitions, not leaps, from one quantum state to another when it absorbs or emits photons and that the energy of the states has quantized values. The word *transition* does not carry the same connotation that *leap* does within the paradigm of classical physics. If an asteroid hit the Earth, the Earth's orbit around the Sun would change, and the change in energy could theoretically take on a continuum of values. The change in the Earth's orbit would also be instantaneous. This example from classical physics belongs to a different paradigm than the paradigm of quantum theory. In the quote above, Ferris's words in boldface are nonsense and defy rational logic. Is the electron a magician performing a disappearing act? Some of the

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[4] Timothy Ferris, *Coming of Age in the Milky Way* (1988; repr., New York: Perennial, 2003).

objections to quantum theory are like Bishop Berkeley's criticism of fluxions in Newton's calculus, and are based on the confusion brought about by mixed paradigms.

The Heisenberg uncertainty principle, which is derived from quantum mechanics, puts limits on how well the position and momentum (mass times velocity) can be simultaneously known. Thus, there is a fundamental indeterminacy in quantum mechanics. This principle says that the more certain the position is measured, the less certain the momentum can be measured, and vice versa. This principle does not apply to a single measurement but to an ensemble of measurements for which the statistics of the standard deviations can be computed.

The Danish physicist Niels Bohr promulgated the probabilistic interpretation of quantum theory, called the Copenhagen interpretation in his honor. It was never accepted by Einstein or even Schrödinger. The paradigm of quantum theory is very different from classical physics. The relationship between the microscopic subatomic world of quantum theory and the macroscopic world of classical physics has led to some interesting paradoxes, like the famous Schrödinger's cat paradox. To say that light is both a wave and a particle at the same time is an antinomy, or contradiction. To say that light sometimes behaves like a wave (e.g., diffraction) and at other time behaves like a particle (e.g., photoelectric effect) is a paradox. The Einstein-Podolsky-Rosen paradox shows that quantum mechanics has the disturbing properties of spooky action at a distance and quantum entanglement. All the paradoxes of relativity have logical resolutions, like the twin paradox. However, the paradoxes of quantum theory have not been sufficiently resolved and remain mysteries. The observer is an integral part of the process in these paradoxes of quantum mechanics. This led Einstein to pose the question to a friend on an evening walk, "Does the moon still shine if we are not looking at it?" Some attempts to resolve these paradoxes strain credulity, like the Many World interpretation of quantum mechanics. Physicists are still arguing over the meaning of the wave function, whether it represents reality or is just a mathematical construct for calculating probabilities.

Einstein and others spent years trying to find a deterministic explanation of quantum theory, to no avail. The effort has been abandoned. No one disagrees that quantum theory has been hugely successful in explaining phenomena in the subatomic world. It works marvelously well. The controversy has been in the interpretation of the theory. Is quantum theory just a mathematical artifice that describes the outcomes of experiments in the subatomic world in probabilistic terms but has no fundamental basis for describing reality? Is the Copenhagen interpretation, or the Many World interpretation, correct that the subatomic world is fundamentally indeterminate? The old guard has died off. The next generation of physicists has embraced various forms of probabilistic interpretation of quantum theory.

There are other reasons why cosmologists desire a quantum theory of gravity besides to overcome the singularities of general relativity. Scientists with a materialistic worldview do not like a universe that is determined by some well-tuned initial conditions. The initial conditions would include the fundamental constants of physics, like the gravitational constant, the speed of light, Planck's constant, the fine structure constant, etc. They readily admit that these constants have such precise values so as to permit atoms to exist, nuclear synthesis to exist in stars that provide energy necessary for life, and chemical elements to exist that are essential for life. How did these constants just turn out to have the values necessary for life? A quantum theory of gravity may eliminate the singularity at the beginning of the expanding universe and at the end of its contraction phase of the closed model, and provide an infinite cycle of expanding and contracting universes. Some hypothesize that our current universe is just one cycle among an infinite number, or one universe among many universes (multiverse). According to these hypotheses, the values of the physical constants have had many different values for other universes, but for our universe they have the unique values necessary for life. They have even elevated this idea to a principle, called the anthropic principle, which states that the reason the current universe has the initial conditions that support the existence of life is because we are here. This is obviously circular reasoning.

It is difficult for a lay person not trained in science to distinguish between physics and metaphysics, and between well-established physical theories and wild speculation. When a scientist like Carl Sagan makes the statement, in the famous *Cosmos* series on TV, that "the cosmos is all that is, or ever was, or ever will be," he is not basing it on physics but on metaphysics, a belief in philosophical materialism. There is nothing new here, because Aristotle promoted the same materialistic worldview, that matter is eternal. Physicists have spent much effort in attempting to develop a quantum theory of gravity, but as yet they have been unsuccessful. Invoking the idea of multiverses to explain why the physical constants are fine-tuned to support life is pure speculation.

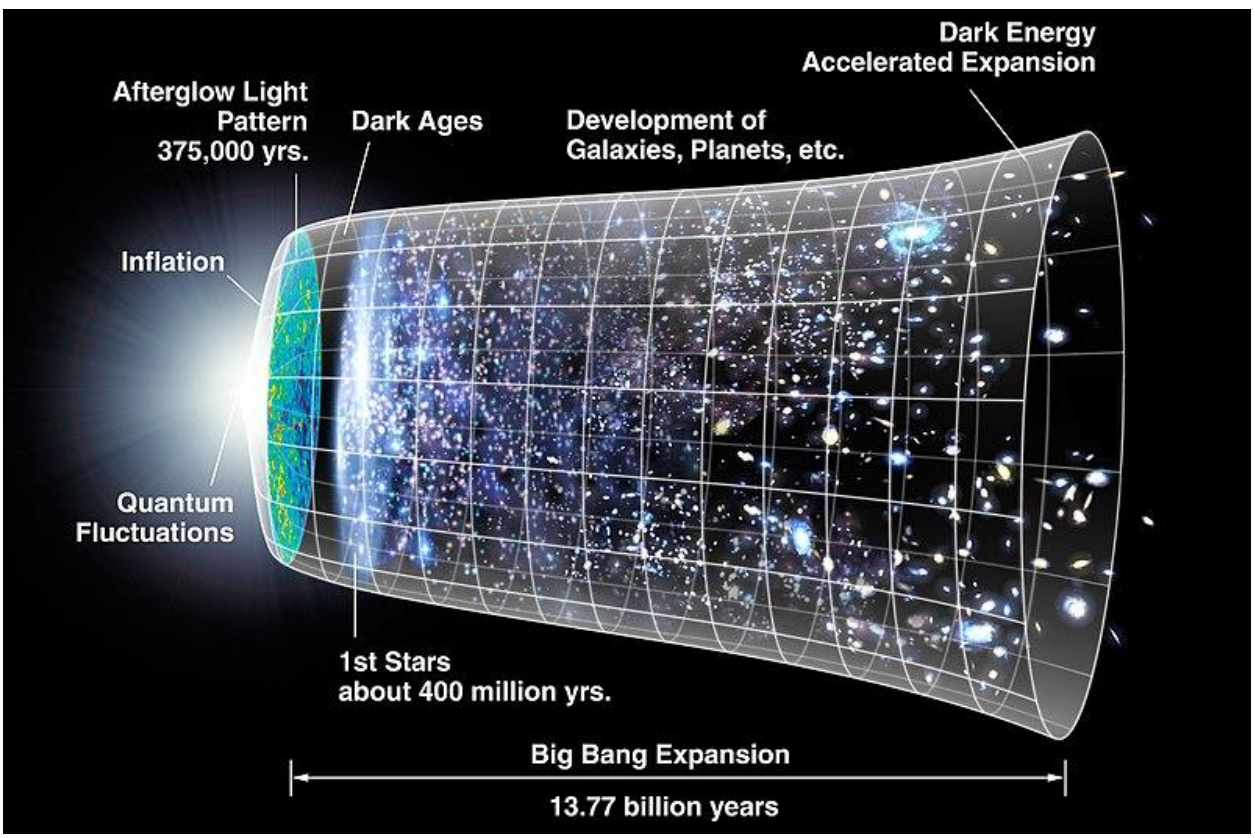
The critical parameter that determines which of the three standard Big Bang models is the correct one is the current density of matter and energy in the universe. There is a critical value of the density of matter and energy corresponding to the flat model. If the density of matter and energy in the universe is greater than this critical value, then the universe is closed. If the density of matter and energy in the universe is less than this critical value, then the universe is open. If one adds up all the matter and energy as observed from visible light from all the galaxies, one arrives at a density of matter and energy much less than the critical density. This implies that the universe is open. From studying the dynamics of galaxies, astronomers have deduced that there must be a lot of mass in the galaxies that does not emit visible light. This mass has been called dark matter. When one adds the contribution of dark matter to the density of matter and energy in the universe, one still gets a value much less than the critical density.

Direct measurements of the curvature of three-dimensional spatial geometry have been made by observing the anisotropy of the CMBR in the BOOMERANG experiment and in the Wilkinson Microwave Anisotropy Probe (WMAP). The results of these experiments show that the density of matter and energy in the universe is within 1 percent of the critical density. If the universe is that close to being spatially flat now, it was extremely close to being spatially flat 13.77 billion years ago at the beginning of the universe. This has been called the flatness problem. Why did the initial conditions of the universe have the density of matter and energy so extremely close to the critical value to cause the universe to be nearly flat? Is it another example of the fine-tuning of the constants of physics? Cosmologists are divided as to whether this is really a problem that needs an explanation.

Physicist Alan Guth proposed a solution to the flatness problem (and the horizon problem concerning the reason for CMBR being very nearly isotropic) by hypothesizing the existence of dark energy associated with empty space or with just the geometry of space itself. Dark energy causes the universe to undergo a rapid expansion during a very short period at the beginning of the universe. The rapid expansion causes any initial value of the density of matter and energy to converge rapidly to the critical value for a flat universe. This avoids the fine-tuning of the value of the initial density of matter and energy in the universe. The modification to the standard Big Bang model proposed by Guth is called the inflationary model. The dark energy is associated with some unknown mysterious form of matter. It is equivalent to having a cosmological constant in Einstein's field equations of general relativity. The cosmological constant represents a constant energy density of empty space. Perhaps it was not Einstein's greatest blunder to introduce the cosmological constant into his field equations after all.

Two independent teams of scientists measured the redshifts of distant supernovae to determine whether the expansion of the universe is accelerating or decelerating. The standard Big Bang model predicts the expansion to be decelerating. However, both teams determined that the expansion of the universe is accelerating. This result is consistent with the inflationary Big Bang model. The two teams received the Nobel Prize in physics in 2011.

Below is an artist's illustration of the closed inflationary Big Bang model. The bell-shaped surface is a two-dimensional representation of the four-dimensional space-time geometry. Time increases from left to right, and the one-dimensional spatial geometry is represented by the circles on the bell-shaped surface. Two spatial dimensions have been suppressed because they are impossible to illustrate in a drawing that humans can visualize. The volume inside and outside the bell-shaped surface is non-physical, or non-observable. The physical universe only consists of the bell-shaped surface. All the galaxies lie on circles on the bell-shaped surface, and are receding from one another because the circles are expanding in size as time increases.



The Big Bang is the best cosmological model that fits the experimental data. The model itself says nothing about how the Big Bang got started or how the universe came into existence. Statements to the effect that it was a cosmic accident that happen by chance, that it just exploded into existence from nothing, or that it was self-generated by gravity are metaphysical statements based on a materialistic worldview and are not based on physics or even logical reason. (See Jeff Zweerink's book *Escaping the Beginning?* for a detailed discussion of whether the universe had a beginning.[5]) So why have Christians been so hesitant to accept the Big Bang? Some have not been hesitant. For example, in the movie *God's Not Dead*, Josh, the main character, uses the Big Bang in his philosophy class as evidence that there is a Creator because it indicates the universe did not always exist but had a beginning. In his address to the Pontifical Academy of Sciences on October 27, 2014 Pope Francis said "the Big Bang, which now stands at the origin of the world, does not contradict the intervention of a divine creator, but demands it." The problem for many evangelical Christians with the Big Bang, however, is its timeline, particularly for those who adhere to a literal 24-hour-calendar-day interpretation of Genesis 1. There is also the problem of the Big Bang's guilt by association with Darwinian evolution, which also requires a long timeline. However, Hugh Ross, in his book *The Creator and the Cosmos* argues that even 13.77 billion years is not long enough for life to evolve from nonlife given the extreme low probability of this happening from undirected, natural processes.[6] One can accept the Big Bang on its own merits without accepting Darwinian evolution. However, many evangelicals fear that a nonliteral interpretation of "day" in the Genesis creation account would undercut the inspiration and authority of Scripture. Is this not like the Copernican controversy?

In 2000, the Presbyterian Church in America (PCA) commissioned a study on the interpretations of Genesis 1–3.[7] The committee found that four different interpretations of Genesis 1–3 are consistent with the view that the Bible is the inerrant Word of God. These interpretations are the 24-hour-calendar-day interpretation, the day-age interpretation, the framework hypothesis, and the analogical day interpretation. The 24-hour-calendar-day

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[5] Jeff Zweerink, *Escaping the Beginning?: Confronting Challenges to the Universe's Origin* (Covina, CA: RTB Press, 2019).
[6] Hugh Ross, *The Creator and the Cosmos: How the Latest Scientific Discoveries Reveal God* (Covina, CA: RTB Press, 2018). For more information, see the Reasons to Believe website at https://www.reasons.org.
[7] Report on the Creation Study Committee to the PCA General Assembly, June 2000, at http://pcahistory.org/pca/studies/creation/report.html.

interpretation implies a young Earth and universe. The day-age interpretation does not specify any particular amount of time that a day represents, but those who hold this view typically interpret the day as representing a long period of time. The latter two interpretations consider the day to be figurative and not necessarily a literal amount of time. When one considers the genre of the creation account, there is some hint that the day is not meant to be taken literally. The phrase "morning and evening" is repeated six times, yet the Sun is not created until the fourth day. Morning and evening are defined by the apparent motion of the Sun with respect to the Earth, so what does this phrase mean before the Sun was created? It seems to be more a poetical figure of speech than a literal description of nature.

Al Mohler, in his address *Why Does the Universe Look So Old?* at the 2010 Ligonier National Conference, mentioned Galileo's two books of revelation and stated that each provides truth about God.[8] One book is the revelation of God in nature. The other book is the revelation of God in Scripture. Since they are both revelations of truth, they cannot be contradictory. Theologians call these two books general revelation and special revelation, respectively. Mohler argued that the most straightforward reading of Genesis 1 is the literal 24-hour-calendar-day interpretation, and he said that general revelation should never trump special revelation. That is why he believes the universe is not really old but only has the appearance of age. Different revelations of the same true God cannot be contradictory, but one revelation may contradict an incorrect interpretation, as was the case during the Copernican controversy. Mohler does not want to consider a truly old age for the universe because of the theological cost. An old Earth causes theological tension with some historic Christian doctrines, including a historical Adam and Eve, the fall, original sin, and the need for redemption of the human race. One can still believe in these essential doctrines of the Christian faith and hold to an old Earth, but not without giving up some ideas that have come to be accepted about the garden of Eden and life before the fall. One such idea held by evangelicals who believe in a young Earth is that there was no death in the animal kingdom before the fall, and that physical death for Adam and Eve and all living creatures was a result of the fall. This idea is hard to hold if one does not believe in a young Earth. If the Earth and the fossil record are old, there must have been many generations of

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[8] See Tim Challies, "2010 Ligonier National Conference – Albert Mohler," June 19, 2010, https://www.ligonier.org/blog/2010-ligonier-national-conference-albert-mohler/.

animals that naturally died off before the fall. Although there is theological tension between an old Earth view and some historic Christian doctrines, it is possible to reconcile the two.

There will be points of disagreement between atheists, who believe in naturalism, and theists, who believe in supernaturalism. Both atheists and theists believe in unprovable presuppositions that form their worldviews. The atheist believes the universe is eternal (or came from nothing with no cause) and denies that there is any intelligence behind the intricate design of the universe and of life itself. The theist believes the universe was created by God and the intricate design of the universe reflects his handiwork. Atheists accuse Christians of believing in a God of the gaps. Namely, if there is a gap in our understanding of how something could be explained by natural processes, then Christians will invoke intervention by God.

Newton used this argument with regard to the stability of the solar system. When one considers the gravitational perturbation of the other planets on Earth's orbit, why doesn't the Earth eventually fly off into outer space? This is a nontrivial question. The stability of dynamical systems, like Newtonian gravity of the solar system, has been the subject of modern mathematics. A dynamical system is stable if small changes in the initial conditions cause small changes in the solutions of the system. Mathematicians have proved the stability of the restricted three-body problem, but the stability of the n-body problem, which would apply to the solar system, has not been proved. However, it is not a good idea to invoke supernatural causes for the stability of the solar system, as Newton did. What if mathematicians later prove the stability of the n-body problem? Dietrich Bonhoeffer said in his *Letters and Papers from Prison*,

> How wrong it is to use God as a stop-gap for the incompleteness of our knowledge. If in fact the frontiers of knowledge are being pushed further and further back (and that is bound to be the case), then God is being pushed back with them, and is therefore continually in retreat. We are to find God in what we know, not in what we don't know.[9]

Christian theologians have pushed back on the accusation of believing in a God of the gaps, which has not been as prevalent in Christian thinking as atheists contend. Did Josh and Pope Francis commit the fallacy of God of the gaps? We will let the reader decide. The Big Bang makes a Christian's belief that God created the universe an even more reasonable alternative to

[9] Dietrich Bonhoeffer, *Letters and Papers from Prison* (1953; repr., New York: SCM Press, 1971).

believing in philosophical materialism or naturalism. Christians believe that God created the universe *ex nihilo*, out of nothing, and they really mean nothing. Only an omnipotent God could do that.

Galileo said that the book of nature is written in the language of mathematics and that training in mathematics is required to interpret this book. This is truer today than it was in Galileo's day. The mathematics needed today to describe the physical world is much more abstract than in Galileo's time. For example, four-dimensional Riemannian (or Lorentzian) geometry is needed to describe the curved space-time of general relativity; infinite-dimensional Hilbert space is the foundation for quantum mechanics; and abstract mathematical group theory is used to describe the symmetries found in the theories of elementary particles. (See Stephen Barr's book *Modern Physics and Ancient Faith* for a presentation of the deep significance of symmetry in nature.[10]) In the article "The Unreasonable Effectiveness of Mathematics in the Natural Sciences," Nobel Laureate Eugene Wigner said, "The enormous usefulness of mathematics in the natural sciences is something bordering on the mysterious and . . . there is no rational explanation for it."[11] Is it possible that the world was created by an intelligent Being and that God left his imprint on the world for intelligent beings made in his image to discover?

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[10] Stephen M. Barr, *Modern Physics and Ancient Faith* (Notre Dame, IN: University of Notre Dame Press, 2003).
[11] Eugene Wigner, "The Unreasonable Effectiveness of Mathematics in the Natural Sciences," *Communications in Pure and Applied Mathematics* 13, no. 1 (February 1960).