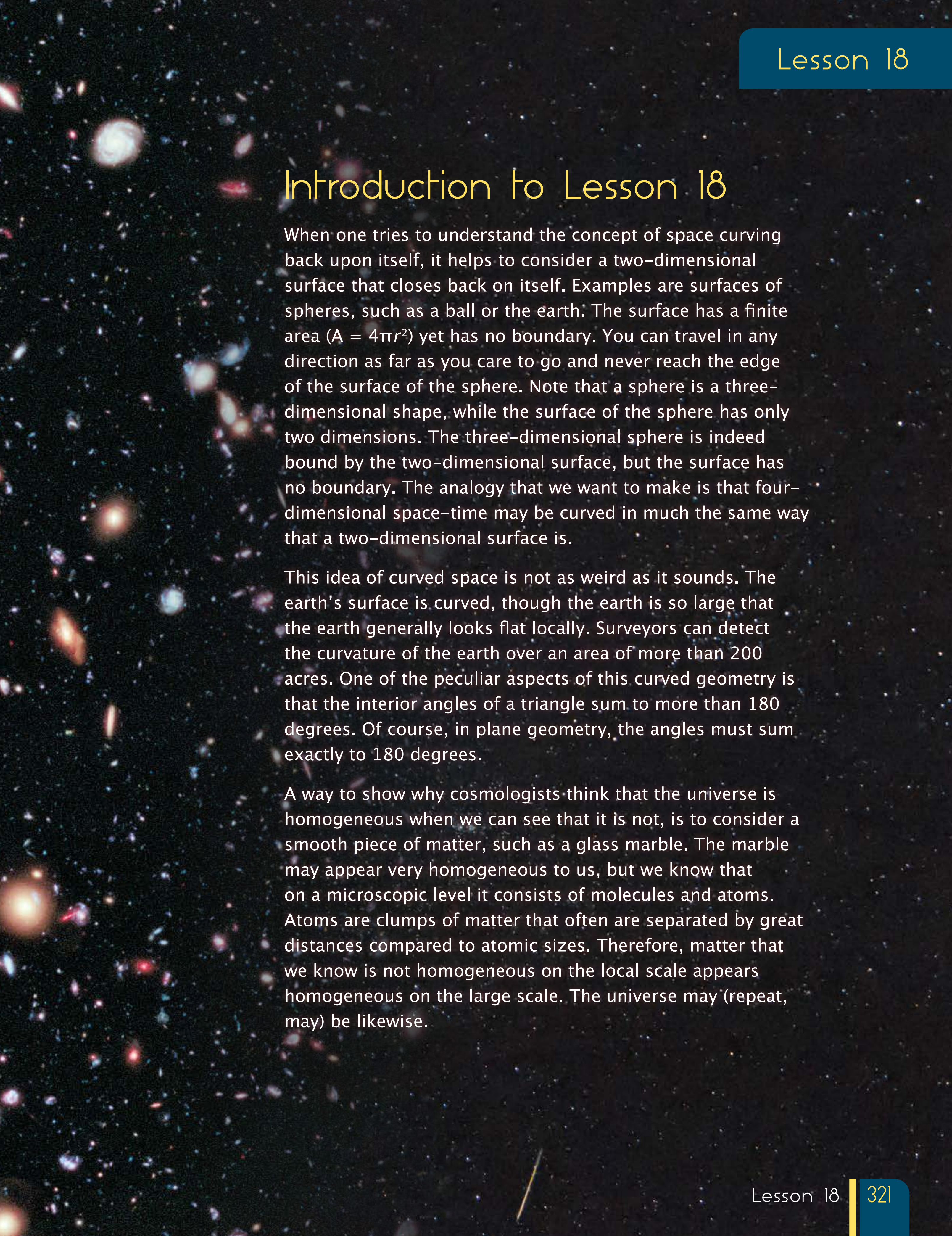


Introduction to Lesson 18

When one tries to understand the concept of space curving back upon itself, it helps to consider a two-dimensional surface that closes back on itself. Examples are surfaces of spheres, such as a ball or the earth. The surface has a finite area ($A = 4\pi r^2$) yet has no boundary. You can travel in any direction as far as you care to go and never reach the edge of the surface of the sphere. Note that a sphere is a three-dimensional shape, while the surface of the sphere has only two dimensions. The three-dimensional sphere is indeed bound by the two-dimensional surface, but the surface has no boundary. The analogy that we want to make is that four-dimensional space-time may be curved in much the same way that a two-dimensional surface is.

This idea of curved space is not as weird as it sounds. The earth's surface is curved, though the earth is so large that the earth generally looks flat locally. Surveyors can detect the curvature of the earth over an area of more than 200 acres. One of the peculiar aspects of this curved geometry is that the interior angles of a triangle sum to more than 180 degrees. Of course, in plane geometry, the angles must sum exactly to 180 degrees.

A way to show why cosmologists think that the universe is homogeneous when we can see that it is not, is to consider a smooth piece of matter, such as a glass marble. The marble may appear very homogeneous to us, but we know that on a microscopic level it consists of molecules and atoms. Atoms are clumps of matter that often are separated by great distances compared to atomic sizes. Therefore, matter that we know is not homogeneous on the local scale appears homogeneous on the large scale. The universe may (repeat, may) be likewise.

Worldview: Through the Lens

CREATIONIST	EVOLUTIONIST
Knows that God created the universe for man's benefit only thousands of years ago	Believes that the universe came into existence via the big bang 13.8 billion years ago
Recognizes many problems with the big bang model	Because of this bias, does not see the problems with the big bang model
Understands that the universe will end catastrophically, to be replaced by a new heaven and a new earth	Believes that the universe will end, if it ends at all, in a naturalistic way


Two-lobed nebula in the constellation of Sagittarius with one of the hottest stars known and powerful stellar winds generating waves 100 billion kilometers high.

Cosmology

Introduction and Definition of Terms

Like some previous chapters, this lesson discusses many evolutionary ideas. Do not fret. There are some creationary ideas about cosmology.

Cosmology is the study of the structure of the universe. A related term is **cosmogony**, which is the study of the history of the universe. Much of what today passes for cosmology is cosmogony. Even though the term cosmogony is not used much today, you ought to know the difference between the words. A cosmologist is a person who studies cosmology and cosmogony.

The ancient Greeks believed that the universe is eternal. That is, the universe had no beginning and will have no end. This idea persisted in western thought well into the 20th century. Why have people believed in an eternal universe? If the universe had no beginning, then it had no Beginner, or Creator. Therefore, the avoidance of a need for God can be a motivation for believing in an eternal universe. Another reason for believing in an eternal universe is that imagining a beginning for the universe is very difficult. This raises all sorts of questions such as why there is a universe or what was here before. Of course, an eternal universe is contrary to biblical teaching, because Genesis 1:1 declares that the universe had a beginning. The eternal universe is a pagan idea that Christians never should have entertained in the first place.

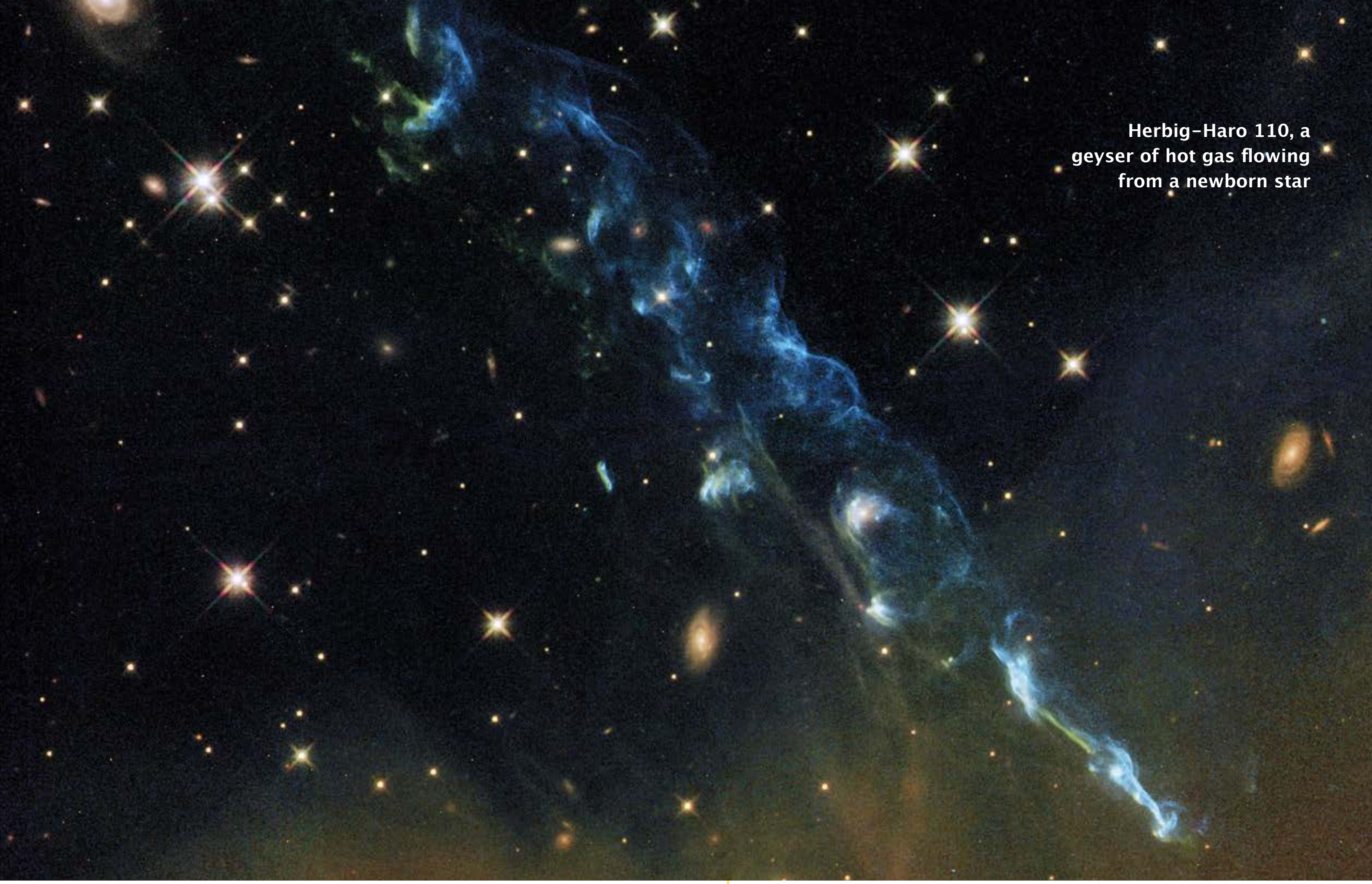
Isaac Newton believed in an eternal universe, though he apparently believed that the earth was not eternal. When Newton devised his law of gravity, he realized that if the universe were eternal, there would have been more than enough time for all the matter in the universe to collapse to its center. The universe obviously is not like this, so how could he avoid this situation? One answer would be to discard the eternal universe. Instead, Newton chose the possibility that the universe is infinite rather than finite in size. That way there would be no center toward which the material would collapse. In such a universe, gravity would affect every particle in the universe in every direction by equal amounts so that all the gravitational forces cancel. Since this model of the universe will not collapse onto itself, we call this a **static universe**. That is, there is no net motion of matter in the universe. The idea of an infinite, eternal, static universe prevailed until well into the 20th century.

During World War I, Albert Einstein (1879–1955) published his theory of **general relativity**. General relativity is the modern theory of gravity.

The bright spot located at the edge of the bluish fan-shaped structure in this Hubble image is a young star, PV Cep, a favourite target for amateur astronomers because the fan-shaped nebulosity, known as GM 1-29 or Gyulbudaghian's Nebula, changes over a timescale of months. The brightness of the star has also varied over time. Images of PV Cep taken in 1952 showed a nebulous streak, similar to a comet's tail. However, these had vanished when new images of the star were obtained some 25 years later. Instead, the blue fan-shaped nebula had appeared. At the same time as this was happening, the star itself was brightening. This provided the light to illuminate the newly formed fan-shaped nebula. This brightening might be related to the start of the hydrogen-burning phase of the star, which would mean that it was reaching maturity. PV Cep is thought to be surrounded by a disc of gas and dust, which would stop light from escaping in all directions.

Newton devised his theory of gravity so that the gravitational forces mysteriously acted through empty space. How does the moon know where the earth is and how much mass the earth has so that the moon can respond under the proper amount of force? In Newton's theory, the moon just does so without any attempt at explanation as to why. Since Newtonian gravity works through empty space, we call this action at a distance. Newton's theory addresses the question of how gravity works, but it doesn't address the more fundamental question of why.

General relativity attempts to answer better the question of why gravity works. Einstein imagined that space is something. Previously, people thought that space was nothing — space was merely a backdrop in which matter and energy operated. For that matter, time wasn't viewed in the same tangible way that matter and energy were. Einstein created a set of equations that described how the presence of matter and energy affected space and time. You can imagine that space is a like a Cartesian coordinate system that you may have used in math class. The difference is that there are four, rather than two coordinates. Three of the coordinates are the three familiar spatial ones, and the fourth dimension is time. We sometimes call these four dimensions "space-time." In the presence of matter or energy, space-time is bent, or warped. You can imagine that space-time is bent much as a piece of graph paper can be (except this is a four-dimensional piece of graph paper!). As objects move through space-time, they follow straight paths. However, the space-time through which objects follow straight lines is curved near where large masses are located. Straight-line motion in curved space-time results in what we call acceleration in how we perceive the world. Thus, the effects of gravity pass through empty space as the result of bending of space-time. Sometimes we refer to this bending


Herbig-Haro 110, a geyser of hot gas flowing from a newborn star

of space-time by large masses as ripples or waves in space-time. Einstein predicted gravitational waves in 1916, but they weren't directly detected until 2016.

However, unlike Newtonian gravity, in general relativity the universe cannot be static, even if it is infinite in size. If general relativity is the correct model of gravity, even a universe infinite in size should eventually collapse in on itself. Realizing this but still wanting to keep an eternal universe, Einstein included a **cosmological constant** in his solution to his equation. The cosmological constant acts as a sort of anti-gravity. Over great distances, the cosmological constant causes space to have a repulsive affect so that it will tend to oppose the inward pull of gravity. By exactly balancing the cosmological constant and gravity, the universe could be static.

Most cosmologists long ago concluded that the cosmological constant is zero. Einstein reportedly later stated that its inclusion in his model was the biggest blunder of his life. However, this is much too harsh. The sort of equation that Einstein solved to get his cosmology always has a constant of integration. In these sorts of problems, the constant of integration often is zero, but sometimes it's not zero. From a mathematical standpoint, there is no reason why the cosmological constant should have any value. The only way to evaluate the constant is to consider the limiting conditions of the problem. Einstein didn't have enough information to determine the constant. Most cosmologists assumed that the cosmological constant is zero. However, in 1999, cosmologists discovered evidence that the cosmological constant may not be zero after all. For several reasons, cosmologists have renamed the return of the cosmological constant as "dark energy."

We ought to explain a few terms that describe the universe. A **bound** universe is one that has a boundary, or an edge. An **unbound** universe has no boundary or edge. A boundary to the universe does not mean an edge to the matter in the universe, but rather it is an edge to space itself. Generally, people conclude that a finite universe must be bound and that an infinite universe is unbound. The reasoning is that if the universe is finite, it must have some end to it, which would amount to a boundary. On the other hand, if the universe were infinite in size, space would go on forever without any boundary. With "normal" geometry, as you may have studied in a geometry class, this is true. However, there are alternate geometries in which a finite universe does not have to have an edge. For instance, if space is curved, then it can close back upon itself, much as the surface of a sphere does. In such a universe if you could look far enough in one direction, you could see the back of your head.

Why consider such a "weird" sort of universe? Besides being a legitimate logical possibility, this sort of geometry avoids some perplexing problems. If the universe had a boundary, we must question what the nature of the boundary is. A boundary would amount to some sort of wall that we could not go through. This would raise all sorts of questions about what the wall is made of that would keep us from passing through. We could also question what is on the other side of the wall. If we could fathom that something is beyond the wall, then that something should be part of our universe, so that the boundary is not quite a boundary. On the other hand, an infinite universe would just go on and on forever. That possibility seems unsettling to many as well. A universe that neither goes on forever nor has a boundary has great appeal. A curved universe is not as weird as you might think. On a local scale, the surface of the earth appears flat. It is only when we consider large distances and areas that the curvature of the earth's surface becomes significant. In similar fashion, the three dimensions of space may appear "flat" locally but may be curved on a large scale.

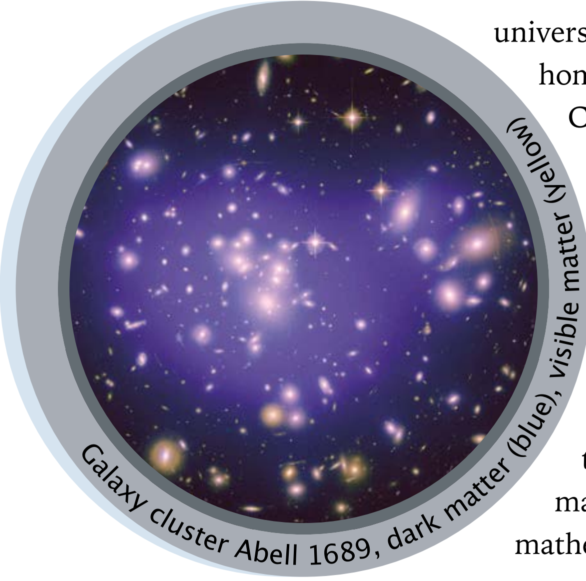

A large, bright concentration of HII and star formation

One important assumption that we make about the universe is that it is **homogeneous**. This means that the universe has the same properties throughout. Since we have not traveled everywhere in the universe (far from it!), this merely is an assumption. However, this is a very reasonable assumption, one that makes science possible. If we assume that the properties of the universe change from place to place, then we can never be sure that if we repeat an experiment in various places that the results would be the same. All evidence that we have suggests that the universe is homogeneous in this way.

More specifically, the type of homogeneity that cosmologists consider refers to density or to the appearance of matter throughout the universe. Cosmologists assume that the universe looks about the same everywhere. Is this true? Locally, it is obvious that this is not true. What you see inside and outside of your classroom is different. What we see on the earth is very different from what we would see on the moon. For that matter, most locations in the universe are far removed from any stars or planets, so a typical view of the universe would be very different from what you and I see all the time.

But when cosmologists say that the universe is homogeneous, they mean for us to ignore the local things and look at the universe as a whole. We should ignore planets (including the one that we live on), stars (including the sun), and even nearby galaxies. Instead, we should look at distant galaxies. In every direction that we look, we see countless galaxies at varying distances that seem to follow the Hubble relation, so it is likely that we would see the same thing from any other location in the universe as well. Homogeneity means that if there were alien astronomers on a distant world examining the universe on the large scale, they would see about the same things that we see.

However, galaxies are not smoothly distributed throughout space. Instead, they tend to clump together into clusters. Even clusters of galaxies seem to clump together. In fact, extensive mapping of the distribution of galaxies show that they tend to be along long intersecting strings and sheets. If the universe were homogeneous, then at a very large scale, galaxies ought to have a uniform distribution. However, at every scale that we have examined the universe thus far, the universe appears clumpy. As reasonable as the assumption of homogeneity is, there is yet no evidence that the universe indeed is homogeneous. Cosmologists assume that on the grandest scale the universe is smooth, because this makes the mathematics work, or at the very least, the clumping of matter in the universe is not significant enough to change the results.



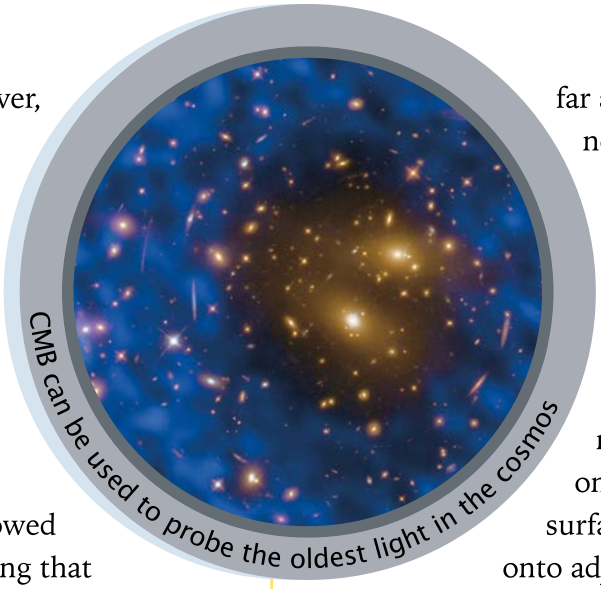
Galaxy cluster Abell 1689, dark matter (blue), visible matter (yellow)

Cosmologists also assume that the universe is **isotropic**. Isotropy means that the universe looks the same in every direction. Of course, on a local scale the universe does not appear isotropic. For instance, during the day, the sun is in one part of the sky; the sun is not in any other direction in the sky. But, as with homogeneity, we must look to the grand scale of things to see isotropy in the universe. At great distances, we see galaxies and quasars randomly distributed in every direction. Isotropy means that we see about the same number and types of galaxies and quasars regardless of which direction that we look. Observation seems to bear this out. However, there are some subtle features of the universe that bring into question whether the universe truly is isotropic.

The Big Bang Model

Despite the difficulties just discussed, cosmologists generally assume that the universe is both homogeneous and isotropic. This assumption is the **cosmological principle**. The cosmological principle usually leads to a model that we call the **big bang**. The big bang is the idea that the universe began 12–15 billion years ago as a sudden appearance of space, time, matter, and energy. Initially, the universe would have been very dense and hot. Like any dense hot gas, the universe rapidly expanded. As the universe expanded, it cooled and became less dense. Eventually, stars and galaxies formed, and late in the process the earth and people developed.

There are several misconceptions about the big bang. First, the name is a bit of a misnomer, because it suggests an explosion. Indeed, many criticisms of the big bang depend upon the big



CMB can be used to probe the oldest light in the cosmos

bang being an explosion. However, the correct view of the big bang model is that the big bang was not an explosion. The big bang model says that the universe abruptly began in a very hot, dense, and expanding state and has been expanding ever since. The only comparison to an explosion is the sudden appearance of the universe followed by a rapid expansion. Recognizing that the big bang was not really an explosion, some supporters of the model have searched for a better name, but so far, they have not found a better name.

Another misconception is that the big bang occurred in one location of the universe and then proceeded to expand into the rest of the universe. Many people imagine that if they had been present at the time of the big bang, they would have seen the big bang expand outward and overtake their position. However, the actual model is that the big bang happened everywhere at the same time so that the big bang filled the universe from the very beginning. However, the universe was much smaller then, so everywhere was much closer together at the time of the big bang. If you have difficulty understanding this point, you are not alone.

The easiest way to think through this is to realize that galaxies in the expanding universe are not moving apart from each other. Galaxies may be at rest with respect to space. It is space itself that expands. An analogy that authors often use is to imagine sequins attached to the surface of a balloon. As you blow up the balloon, the sequins appear to move apart, even though the sequins are not moving. As the rubber in the balloon between the sequins expands, the expansion carries the sequins along. In like fashion, galaxies that are far apart from each other may not be moving with respect to space, but the space between the galaxies is expanding so that the galaxies appear to move apart. Notice that in this analogy the sequins do not start congregated on one portion of the balloon's surface and then move apart onto adjacent, initially unoccupied portions of the balloon. The sequins initially fill the balloon's surface and merely are carried along by the expanding rubber of the balloon. According to the big bang theory, matter and energy filled the universe and then space expanded in a similar fashion.

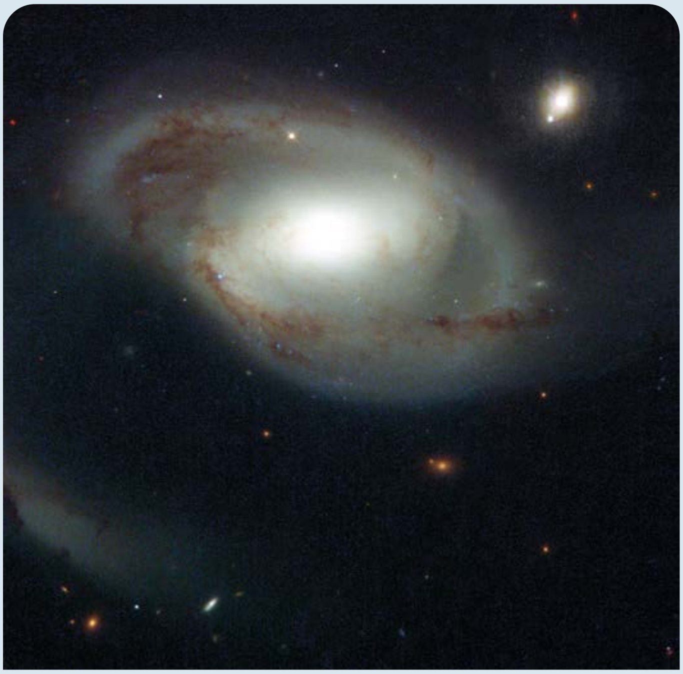
When objects move with respect to space, we refer to their motions as Doppler motions. However, when objects are at rest with respect to space and they appear to move apart solely as the result of the expansion of space, that perceived motion is **Hubble flow**. Hubble flow is very different from Doppler motion, though observationally they appear the same to us. Hubble flow is due to the expansion of the universe, while Doppler motion is due to motion of objects with respect to space. Since objects may move either toward or away from us, a Doppler motion is as likely to produce a blueshift as a redshift. Since the universe is expanding, all spectral shifts due to Hubble flow are redshifts. When a redshift is due to Hubble flow, we say that it is a **cosmological redshift**. If redshifts are cosmological, then the redshifts result from the expansion of the universe and the redshifts truly reflect distance. That is, the Hubble relation tells us the distance. Some people have questioned this. See **Feature 18.1** for more details about this.

FEATURE 18.1

ARE REDSHIFTS COSMOLOGICAL?

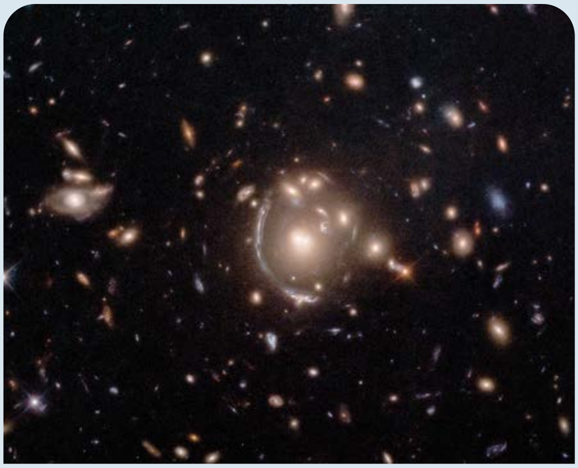
Since the 1960s, the astronomer Halton Arp has pursued observations that question whether redshifts are cosmological. He has found several interesting sorts of data. Arp has photographed pairs of galaxies that appear to be interacting. In some cases, there is a bridge of material connecting the two galaxies. In other cases, a spiral arm in one of the galaxies is distorted in such a way as to suggest that the gravity of the other galaxy has affected it. In either case, both galaxies must be close to each other, and hence about the same distance from us, for these interactions to occur. Yet, when we measure the redshifts, the redshifts of the two galaxies are very different. If we apply the Hubble law to find the distances of the galaxies, we find that the galaxies are at vastly different distances, which would make interactions impossible.

Another example is a photograph that shows a small galaxy superimposed upon the edge of a larger galaxy. It appears that the smaller galaxy is in front of the larger galaxy. Yet when we compare the redshifts, the smaller galaxy has a much larger redshift than the larger galaxy. If the Hubble relation truly reflects distance, then the smaller galaxy must be much farther away, and hence behind, the larger galaxy. Another photograph shows a large spiral galaxy, from which we can measure the apparent size of the galaxy. Once we know the distance, we can compute the actual size of the galaxy. Using the redshift to find the distance, Arp found that the galaxy is about ten times larger than any known galaxy. Arp concluded that this large size is unlikely, and so questioned the legitimacy of the Hubble relation.



Appearances are deceiving with this odd celestial duo, the spiral galaxy NGC 4319 [center] and a quasar called Markarian 205 [upper right] as they appear to be neighbors. In reality, the two objects don't even live in the same city. They are separated by time and space. NGC 4319 is 80 million light-years from Earth. Markarian 205 (Mrk 205) is more than 14 times farther away, residing 1 billion light-years from Earth. The apparent close alignment of Mrk 205 and NGC 4319 is simply a matter of chance.

Why does Arp question the Hubble relation? He believes that we have fooled ourselves into thinking that quasars are very far away. We base the large distances to quasars upon the assumption of cosmological redshifts. If redshifts do not reflect distance, then quasars are much closer than generally thought, and there is not a problem in identifying their source of energy. Arp has also found that quasars tend to cluster around nearby galaxies. If quasars are very distant, then we would expect them to be randomly distributed, and they certainly should not appear grouped around nearby galaxies. From these data, Arp has inferred that



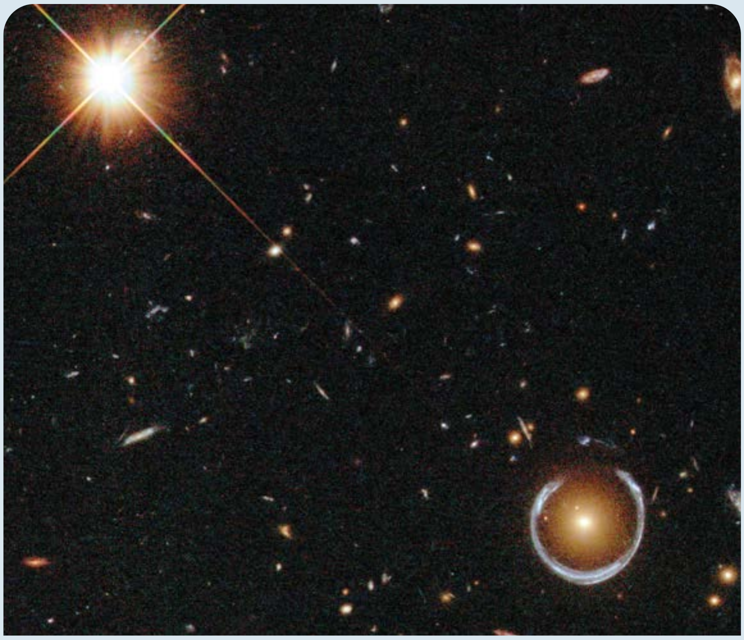
This galaxy, its image distorted by the effects of gravitational lensing, appears as a long arc to the left of the central galaxy cluster.

quasars clump around nearby galaxies. He further surmises that the central galaxies probably ejected the quasars. One problem with Arp's work is that he has not been very convincing in telling us what quasars are and why we do not see any blueshifted quasars, which we would expect to see if they are ejected from nearby galaxies.

What are the consequences if Arp is correct? It is not entirely clear. Arp does not suggest that redshifts never depend upon distance. Rather, he suggests that in at least some situations they do not. It would not be possible to determine when redshifts are cosmological and when they are not. Ultimately, the assumption of cosmological redshifts is related to the concept of an expanding universe. If the universe is not expanding, then all of the cosmology since the 1920s would appear to be invalid. Arp does not go that far. It is very clear that Arp opposes the big bang model, opting in favor of the steady state theory instead.

While most creationists applaud Arp's work, there should be a word of caution. Arp reportedly was an atheist. While creationists share his skepticism of the big bang, his beliefs and cosmology are very different from ours. It should be stressed that creationists do not endorse all of his conclusions, just as he would not endorse many of ours.

Unfortunately, Arp's story does not have a happy ending. After pursuing his work for two decades, Arp amassed some powerful opponents. In the 1980s, several of them conspired to prevent him from gaining any more telescope time to continue this work. In the estimation of many astronomers, his work had never been refuted. His opponents merely were able to silence him. Arp thought that this situation was intolerable. As a result, he took an early retirement from Cal. Tech. He soon took a position at the Max Planck Institute in Germany. Arp remained in Germany until his death.



The Cosmic Horseshoe is one of the best examples of an Einstein Ring. It also gives us a distinctive view of the Universe shortly after creation: the blue galaxy's redshift — a measure of how the wavelength of its light has been stretched by the expansion of the cosmos — is approximately 2.4.

The observed shift of lines in the spectrum of a distant object such as a galaxy or quasar is the sum of Hubble flow and Doppler motion. To determine the Hubble constant, it is important to use only the Hubble flow. Unfortunately, it is not possible to tell directly what portion of a redshift Doppler motion is and how much is due to Hubble flow. Generally, Hubble flow increases with distance, but Doppler motion probably has some random value centered on zero that is independent of distance. Note that Hubble flow is always positive, while Doppler motion can be either positive or negative. As distance increases, Hubble flow increasingly dominates the observed redshift. The result is that Doppler motions likely swamp the feeble Hubble flow of nearby galaxies. On the other hand, distant galaxies have such large Hubble flows that we can safely ignore any Doppler motions. Therefore, it is best that we use distant galaxies to determine the Hubble constant. However, the distances of faraway galaxies are difficult to measure accurately. Usually, calculations of the Hubble constant rely upon nearby galaxies, with allowances made for Doppler motions. There is some disagreement as to how to account for this, which leads to much of the uncertainty in the Hubble constant.

NGC 7727 in constellation Aquarius is believed to be the result of a clash between two galaxies. Dark energy is the mysterious force permeating the Universe and causing accelerating expansion.

Another misconception about the big bang and the expansion of the universe is that the universe must be expanding into something. It is not. The universe is merely getting larger. As space expands, it does not expand into anything. Instead, points in space merely get farther apart. The analogy to the expanding balloon probably fuels this misconception. The balloon is obviously expanding at the expense of space surrounding it. However, the surface of the balloon, a two-dimensional object, is expanding into three-dimensional space. The expanding universe is a three (or four, with time included) dimensional thing. The universe could be expanding into some other higher dimensional space, but we have no concept of that. Imagine if you were confined to the surface of the balloon. You would be restricted to two dimensions and would have no concept of the third dimension. As your balloon world expanded, you would have no idea that it was expanding into anything else.

Another misconception about the big bang is that there must have been something here before the big bang. Time began with the big bang, so there could not have been time before the big bang. In fact, the concept of "before the big bang" makes no sense. Furthermore, since the big bang marked the beginning of space, "here" did not exist prior to the big bang. In other words, here was not here then, and then was not then then either. Some Christians see the fingerprint of God in the big bang. **Feature 18.2** discusses the danger of making the big bang part of our apologetics.

FEATURE 18.2

SHOULD THE BIG BANG BE PART OF OUR APOLOGETIC?

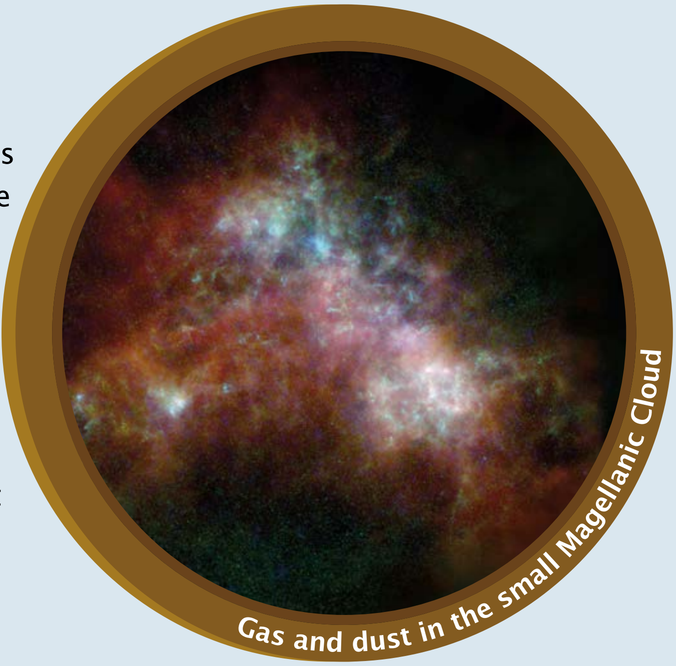
The big bang theory states that the universe and time had a beginning. This is contrary to the steady state theory and much of Western thought since the time of the Greeks. The "In the beginning…" of Genesis 1:1 suggests the beginning of all things, including space and time. Some Christians have noted the similarity of the big bang theory and Genesis 1:1 on this one point and have concluded that the two are in harmony.

If this is all the detail that the biblical creation account contained, then that may be true. However, the creation account has much more detail than that. For instance, in the big bang cosmogony, the earth formed much later than the creation of the universe, but in the biblical account, God made the earth at the very beginning. Acceptance of the big bang usually leads to acceptance of theistic evolution or progressive creation. It is impossible to harmonize either of these viewpoints with the Bible in a manner that is biblically faithful. For instance, one must use creativity to explain how plants existed before the sun, or how birds existed before land animals.

Unfortunately, reinterpreting Scripture in terms of science usually handles these and numerous other difficulties. This is a dangerous precedent, because it signals a belief that we are better to trust science to understand certain things. People who take this approach are very subtly indicating that science is of higher authority than the Bible.

It is very misleading to distill the big bang and the creation account down to one common essential, that the universe had a beginning, and then to state that this amounts to "complete harmony." There is an old saying, "the devil is in the details," that is doubly true here. To claim one common element and then liberally reinterpret one account in terms of the other amounts to deceptive advertising.

Many who teach the agreement between the big bang and the Bible argue that the big bang requires that God exist. We examine this questionable assertion in **Feature 18.3.** There is another danger missed by proponents of this apologetic. Science is a changeable thing. Much of what was scientific "truth" a century ago no longer is true. If the past is any guide, it is very likely that eventually the scientific world will discard the big bang theory. If we make the big bang an important part of our apologetic, then what will happen to our apologetic when the big bang is no longer a valid scientific theory?



Gas and dust in the small Magellanic Cloud

FEATURE
18.3

DOES THE BIG BANG PROVE THAT GOD EXISTS?

Those who believe that the big bang proves God's existence use the causality argument. The principle of causality is an ancient idea. Everything that happens is caused by something else. Conversely, every cause has an effect. Every effect is in turn a cause for a new effect, and that new effect is a cause for still another effect. Thus, there are countless seemingly never-ending chains of cause and effect through time. For instance, your parents' concern for you was the cause of them placing you in the school setting that you now find yourself. That effect was in turn the cause of you ultimately being in this class. Being in this class was the cause of you having this textbook. Having this textbook was the cause of you reading this sentence at this moment. The author had a different long chain of cause and effect that led him to write the words that you now read.

The chain of cause and effect is interesting, but it gets more interesting when we view the chain in reverse. A cause precedes every effect. For instance, why does this textbook exist? It exists because I decided to write it. Why did I decide to write it? I realized that there was a need for such a book. There is a long chain of questions from there that goes back to how and why I became interested in astronomy and ultimately why I exist. For instance, if my parents had never met, you would not be reading this.

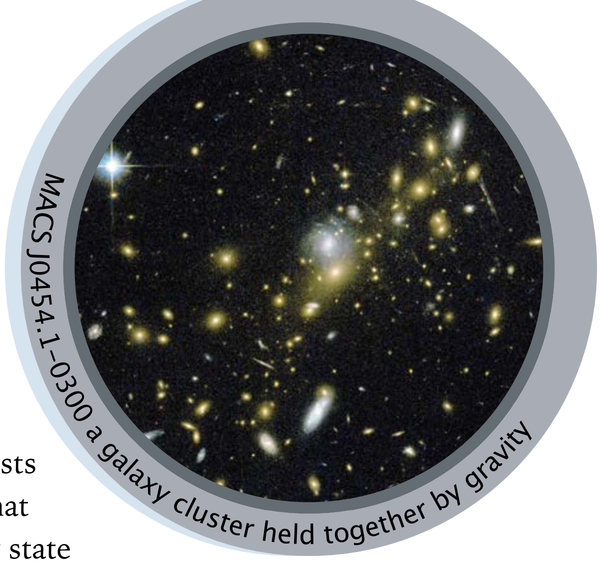
Medieval scholars used the causality argument to show that God must exist. Every effect is preceded by some cause, but every cause is in turn the effect of some previous cause. Medieval scholars reasoned that in the beginning there must have been some Uncaused Cause. That is, there must have been some cause that had no prior cause. This Uncaused Cause must be God.

In like fashion, many Christians today think that the universe must have had a cause. We may ask the question, "What caused the big bang?" To which the answer is "God." However, does that prove that God caused the big bang? A cause must necessarily precede its effect in time. A cause cannot occur after or at the same time that its effect does. This requirement also demands that causality work within time. If there is no time, causality does not operate. For anything to cause the big bang, that cause must exist before the big bang does. However, the big bang marked the beginning of time, as pointed out in the text. The concept of "before the big bang" makes no sense. Therefore, to insist that God must have caused the big bang is to force the use of causality where it is not valid.

It is a logical possibility that the big bang was the first, or Uncaused, Cause. If the big bang is the Uncaused Cause, then God is unnecessary. To insist that God must be the cause of the big bang simply does not follow from logic. One could respond that there is a causality principle that works apart from time, but there is no evidence of that. Some may object with the question, "What caused the big bang?" However, the atheist can reply, "Who made God?" There can be only one Uncaused Cause. We can choose between a Deity and the big bang, but logic cannot demand both. Christians who fail to see this either do not understand causality or the big bang theory, or both.

The Steady State Model: An Alternate Cosmology

While the big bang is by far the most popular explanation of the universe today, there are other possibilities. For instance, the **perfect cosmological principle** states that the universe is always homogeneous and isotropic. Under this assumption, not only does the universe look the same from every location and in every direction today, the universe must always have looked the same in the past and will look the same at all times in the future. As space expands, the universe must get less dense and cooler, so how can this be? The universe can remain homogeneous and at the same temperature as it expands only if the density remains the same. This requires that new material come into existence at a constant rate. You ought to recognize that this is a violation of the law of conservation of matter. However, the law of conservation of matter is merely a description of how we observe the world to operate. The rate of creation of new matter required to maintain a constant density as the universe expands is very small. The amount of new material introduced each year in the volume of a large room would be less than a hydrogen atom. This little bit of matter would escape our notice, so that the conservation of energy would still appear to be valid.

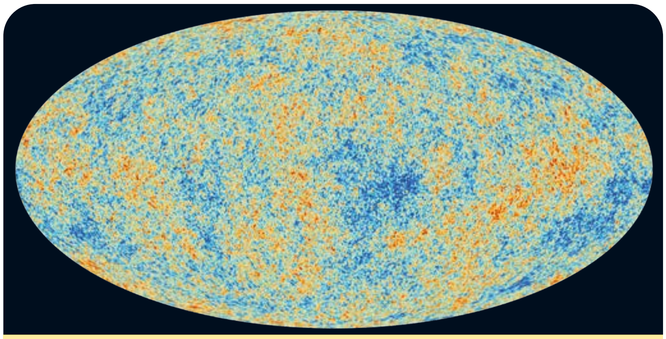

MACS J0454.1–0300 a galaxy cluster held together by gravity

The perfect cosmological principle leads to a model where the universe never changes, so cosmologists have called this model the **steady state**. Another name is the continuous creation model, so called because it demands that the universe create new matter as we just discussed. A steady state universe never changes, so it would have no beginning or end. If the universe has neither beginning nor end, then it is eternal. For many years in the middle of the 20th century, the steady state theory was very popular, because it agreed with the eternal, infinite universe, a concept believed since ancient times. Some cosmologists claimed that the steady state theory was so beautiful that it just had to be true. Since there was no beginning of a steady state universe, there is no place for a Creator in this model. Therefore, the steady state theory is the ultimate atheistic model. Many people think that the big bang model demands that there be a Creator, but **Feature 18.2** shows that that is not the case either.

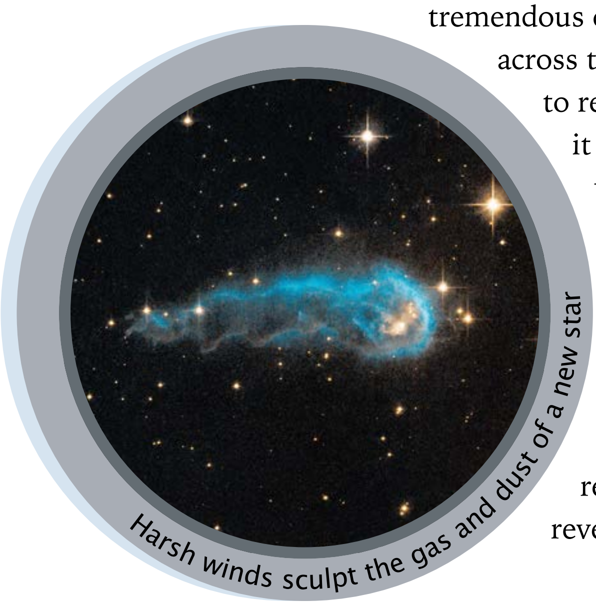
The Cosmic Background Radiation

Until 1965, most astronomers probably believed the steady state model. Why? They considered the steady state model theory a simple, beautiful model. There is a bias in favor of the universe being so. But today very few people believe the steady state theory. Why? In 1964, two Bell lab scientists, Robert Wilson (b. 1936) and Arno Penzias (b. 1933), discovered the **cosmic microwave background radiation** (CMB). This discovery was so important that Penzias and Wilson received the Nobel Prize in physics in 1978. The CMB is made of many photons in the microwave portion of the spectrum coming toward us from every direction. While each photon contains little energy, there are so many of them that together they account for a significant portion of the energy in the universe. The CMB has a blackbody temperature of just under 3 K, which we can take as the temperature of the universe.

According to the big bang model, the early universe contained ionized hydrogen (protons and electrons), making the universe opaque. This opacity trapped radiation, and kept it coupled to the ionized matter. As photons were emitted, they would have traveled only a fraction of an inch before they were reabsorbed, only to be reemitted once again to repeat the process. But about 380,000 years after the big bang, the temperature of the universe would have cooled to the point that the protons and electrons would have formed stable atoms of hydrogen for the first time. This recombination of atoms would have rendered the universe transparent for the first time, allowing radiation to decouple from matter and travel great distance. Cosmologists call this alleged event the age of recombination.


The cosmic microwave background (CMB) shows tiny temperature fluctuations that correspond to regions of slightly different densities, blue is cold, red is hot.

The photons of light emitted right after the age of recombination should be visible as uniform radiation coming from all directions in space. But since this radiation would have traveled tremendous distance across the universe to reach us now, it would have undergone huge redshifts. Calculation of the conditions at the age of recombination reveals that the temperature of the universe then would have been about 3000 K. Thus, the photons ought to have a blackbody spectrum of that temperature. While the photons have traveled toward us over billions of years since the age of recombination, the universe has expanded a thousand-fold. Therefore, the photons should have experienced a thousand-fold redshift so that their temperature is now 2.73 K. A cosmologist predicted the existence of the CMB about 15 years before the discovery of the CMB. The big bang model did not predict a precise single value, but rather it predicted a range of temperature. The observed 2.73 K temperature is near the low end of that temperature range.


Harsh winds sculpt the gas and dust of a new star

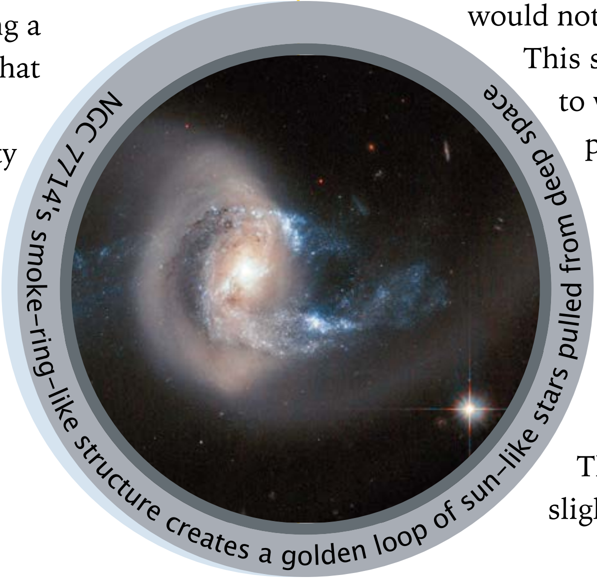
The CMB is a prediction of the big bang model, but the steady state model does not predict it. This is because according to the steady state model, the universe has always been as it is today, and so there was never a time in which it had a 3000 K temperature. Since the steady state model does not predict the CMB and the big bang model does, most astronomers abandoned the steady state model shortly after the discovery of the CMB. There are some notable exceptions, such as Sir Fred Hoyle (1915–2001). Hoyle was a famous British astrophysicist who pursued work on the steady state model for decades until his death. He attempted to develop a steady state model that explained the CMB, but most astronomers do not think that he ever succeeded. Since creationists share Hoyle's rejection of the big bang theory, many creationists favor Hoyle's explanation of the CMB, though they disagree with his cosmological model.

The Big Bang and the Christian

Many Christians accept the big bang model. One feature that these Christians like about the big bang model is the fact that it clearly states that there was a beginning for the universe. This one aspect agrees with the Genesis account, unlike the steady state model. However, does this mean that the big bang model is consistent with the Genesis account of creation? There are numerous problems. One obvious problem is the time involved. The best reading of the creation account is that it took six normal days a few thousand years ago. The big bang would have happened 10–15 billion years ago.

To many Christians who have adopted the big bang model, the big bang serves as a proof for God's existence. Their reasoning is that the big bang required a cause. The only cause that they can identify is a deity. However, there is a logical fallacy in this, as discussed in **Feature 18.3**. Far from being an evidence of God's existence, the big bang is the ultimate atheistic theory.

Another difficulty is that we always should keep in mind that all scientific theories are subject to later revision and even abandonment. The history of science is littered with discarded wrecks of theories that were once considered beyond doubt. If we make the big bang a key part of our apologetics, what happens to our apologetics when the scientific community abandons the big bang model?


NGC 7714's smoke-ring-like structure creates a golden loop of sun-like stars pulled from deep space

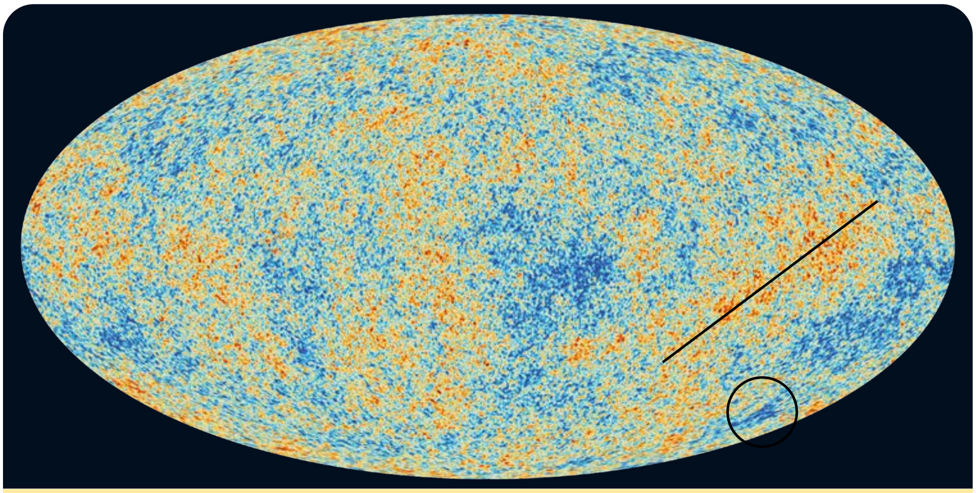
If the big bang is not a model that is consistent with biblical creation, what is the creation model of the universe? We currently do not have a well-developed creation model. Only in recent years have creation scientists begun to develop original ideas about cosmogony and cosmology.

Problems with the Big Bang Theory

Those who support the big bang model generally give three evidences. The CMB is one proof for the big bang often cited. As previously discussed, this was a good prediction of the model. Alternate explanations generally have failed to explain adequately the CMB. However, in the next lesson we shall explore a possible explanation for the CMB within a biblical model of cosmology. While the CMB is an impressive prediction of the big bang model, there are difficulties with it.

For instance, to explain the structure that we see in the universe today (galaxies and clumps of galaxies), from the beginning of the big bang there must have been regions in the universe where the density was slightly greater than in other regions. The regions of greater density would have had greater than average gravity. The regions of greater gravity would have acted as seeds to attract matter to form the structure that we see today. Otherwise, if the universe were perfectly smooth, then galaxies, stars, and planets would not have formed. Consequently, we would not be here to see the universe. This sort of discussion can lead to what we call the anthropic principle, a topic further explored in **Feature 18.4**.

These small variations in density in the early universe ought to show up as slight variations in temperature in the CMB. That is, there ought to be slightly warmer and cooler temperatures in different directions in space. Cosmologists determined that these fluctuations in temperature would be on the order of one part in 10,000. NASA designed the COBE (COsmic Background Explorer) satellite to look for these temperature fluctuations. Launched in 1989, COBE had a two-year mission during which it mapped the entire sky in the portion of the spectrum where the CMB is strongest. The two years of data collection revealed a perfectly smooth CMB, in direct conflict with the model predictions.


An all-sky CMB map with the location of the Axis of Evil indicated by a line and a circle around the cold spot.

After some very sophisticated statistical analysis of the COBE data, a team of scientists found evidence of slight variations in the CMB in the COBE data, but on the order of about one part in 100,000 rather than the predicted one part in 10,000. Later experiments confirmed these temperature fluctuations. This was hailed as additional confirmation that the big bang model is true. Some scientists even claim that the predictions and measurements agree exactly. But how can that be, when the measured temperature fluctuations were only $\frac{1}{10}$ those predicted by the model? There indeed are temperature fluctuations, but they are far from the predicted level. Theorists altered the big bang model to fit the data. These are very loose rules for verification. Cosmologists can change the model whenever necessary to account for new data. With such rules, it is no wonder that so many people believe the big bang model.

But there are other problems in the details of the CMB. The Wilkinson Microwave Anisotropy Probe (WMAP) spacecraft measured the CMB with great precision during its mission (2001–2010). Its data revealed two interesting features in the CMB — the Axis of Evil and the CMB Cold Spot. The Cold Spot is a region in the CMB that is significantly cooler than the rest of the CMB. The Axis of Evil is a long region of space that is significantly warmer than average temperature. Most interestingly, the Axis of Evil is aligned with the ecliptic. Neither the Cold Spot nor the Axis of Evil were expected from the big bang model, nor can the big bang model explain them. Furthermore, why should a cosmic radiation field have a large anomaly that is oriented with the earth's orbit around the sun?

Many scientists assumed that the CMB Cold Spot and the Axis of Evil were not real but were instead noise in the WMAP data. It was expected that both would disappear with more precise data. That opportunity came in 2009 when ESA launched Planck, a third satellite dedicated to the study of the CMB. Both the CMB Cold Spot and the Axis of Evil remain in the Planck data, indicating that both are real. There is no explanation for either in the standard big bang model.

FEATURE 18.4

THE ANTHROPIC PRINCIPLE

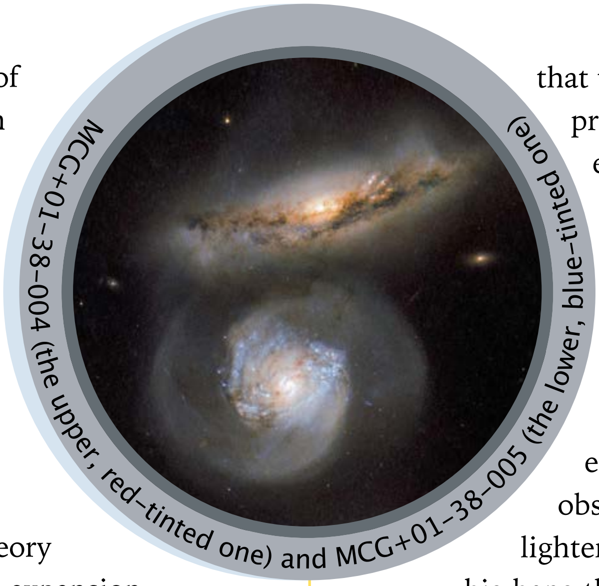
The Australian physicist Brandon Carter (b. 1942) coined the anthropic principle in 1973, though elements of the anthropic principle had been around far longer. The name comes from the Greek root *anthropos*, meaning "man." We get the word anthropology from the same root. The anthropic principle is the idea that there are certain characteristics about the universe that seem to demand that humans exist. The example from the text is the amount of clumping in the early big bang universe. If the early universe were too smooth, then no structures such as galaxies, stars, planets, and ultimately, people would have come into existence. On the other hand, if the early universe had been too clumped, then nearly all matter would have formed into massive black holes so that no galaxies, stars, planets, and hence people would have formed. The range in the distribution of matter in the early universe that would have led to our existence is extremely narrow. Why, then, does the universe exist as it does with people?

There are many other such examples. For instance, if the physical constants that control the structure of matter were slightly different, then certain elements would not exist as they do. If carbon were slightly different, it would not be able to form all its marvelous chemical bonds, and life would not be possible. If oxygen and hydrogen were different, would water, another essential ingredient for life, exist? All these numerous examples suggest that the universe exists as it does for our benefit. If the universe were any different from how it is, we would not be here.

To many Christians this sounds like an evidence for God's existence. However, we should be very careful. Many parts of the anthropic principle assume that the big bang, billions of years of age, and evolution are true. Creationists reject these ideas, and hence the associated anthropic reasoning. For instance, if the big bang never happened, then the smoothness of the early universe is not an issue. Some Christians accept the big bang and a vast age for the universe. To them, the anthropic principle is a very important argument for God's existence.

Scientists have explored the anthropic principle and mostly have rejected it. Their rejection is based upon a key word in the definition of the anthropic principle above and repeated here with emphasis: there are certain characteristics about the universe that *seem* to demand that humans exist. In 1988, John Barrow and Frank Tipler published *The Anthropic Cosmological Principle*, an exhaustive study of the anthropic principle. The authors concluded that the world only seemed to be designed for man. That is, no matter how contrived the world appears to be, this is the way the world is, and it could be no different.

Rather than start with what amounts to atheistic ideas of science, is it not better to begin with a creation-based approach? We should use our creation model to look for evidence in the world that suggests that it was designed and created for our benefit. There are numerous examples of design in biology, and creationists have used these for a long time. The case for design in astronomy is not as well stated, probably because of the lack of a coherent creation model for astronomy. As a creation astronomy model develops, we will have more evidence of design.


MCG+01–38–004 (the upper, red–tinted one) and MCG+01–38–005 (the lower, blue–tinted one)

A second alleged prediction of the big bang is the expansion of the universe, but this was not a prediction of the model at all. Hubble discovered the expansion of the universe long before the big bang model was developed. Indeed, the big bang theory was proposed to explain the expansion of the universe (the steady state theory was developed to explain the expansion of the universe as well). This is putting the cart before the horse. It is improper to use data that necessitated or guided the creation of a theory as evidence for the theory. To do so is an example of circular reasoning.

Circular reasoning happens when someone starts with an assumption or bit of information, develops a conclusion based upon the starting information, and then uses the starting information as "proof" that the conclusion is true. People use this sort of reasoning more frequently than we realize. It is very easy to fall into this alluring trap when we wish to establish some pet idea. Another example of this is the evidence for stellar evolution offered by H-R diagrams of star clusters as discussed in lesson 14. Please notice that while circular reasoning itself is a logical fallacy, the idea that we try to support with circular reasoning may be correct. For instance, many of the alleged proofs of God's existence are of a circular nature. Such arguments tend to confirm those who are already convinced of the conclusion but do little to convince those who are not.

The third evidence for the big bang frequently cited is the abundances of the lighter elements in the universe. The lighter elements include hydrogen, helium, and lithium and some of their isotopes. Most books about cosmology claim that the big bang theory correctly predicts the amounts of these elements in the universe. However, one can calculate different versions of the big bang. One of the things that theorists can change in big bang models is the abundances of the lighter elements. Astronomers observed the abundances of the lighter elements before the detailed big bang theory calculations. These abundances were input values in developing the big bang model. It should be no surprise then that these models "correctly predicted" these values when the models were designed to do just that. This too is circular reasoning.

The work of the astronomer Halton Arp (1927–2013) is described in **Feature 18.1**. For years, Arp called into question whether red shifts are always cosmological. Arp has offered many examples of quasars and galaxies for which he thinks most astronomers have incorrectly assumed that red shifts give distances. Many creationists like Arp's work. They reason that if Arp is correct, then we could never be sure when a red shift tells us distance. If we have doubts about the Hubble relation, then can we say with confidence that the universe is indeed expanding? If the universe is not expanding, then the big bang did not happen. But this misunderstands Arp's work. Arp never doubted that the universe is expanding. Rather, he questioned whether all large redshifts are cosmological. Of course, red shifts are real, so if they do not result from the expansion of the universe, then there must be some other explanation for the red shifts. Arp and others have offered several alternate explanations for high redshifts, but all seem to suffer from some difficulties.

Since the mid 1970s, an Arizona astronomer named William Tifft has noticed that red shifts do not fall over a continuous range of values. Instead, red shifts seem to lie near certain values, particularly multiples of $72\,\frac{\text{km}}{\text{s}}$. When we find measurements of a variable that clump near certain values, we say that the variable is quantized. A similar thing happens to energy values in very small systems such as atoms. Energy quantization in small systems forms the basis of quantum mechanics. What does the quantization of galaxies, some of the largest things known, mean? No one knows yet. While most astronomers are suspicious of quantized red shifts, they have not been able to discredit the data. If anything, the data become stronger with time. However, it may be that quantized redshifts are the result of our looking through the clumps of matter in the universe, a subject that we already discussed.

If real, then red shift quantization is a difficulty for the big bang. If red shifts are cosmological, then red shift quantization could mean that we are in the center of a series of shells of galaxies. This would invalidate the cosmological principle, upon which the big bang depends. It would also suggest that the universe has a center, which most versions of the big bang do not allow. Even worse, we are at or very near the center of the universe! This means that we have a very favored place in the universe. If we are the result of random events, what is the probability that we ended up so close to the center of the universe? This not only threatens the big bang theory, but all evolutionary thinking as well. In the next chapter, we will discuss creation-based cosmologies that place the earth near the center of the universe. Thus, while the big bang model may not explain quantized red shifts, this creation cosmology can.

The evidence of the big bang is far less than many people think. The only good evidence for the big bang is the existence of the CMB, though the detail of the CMB does not offer real proof for the big bang. Other so-called “proofs” of the big bang are circular arguments. There are other features of the universe that are difficult, if not impossible, for the big bang theory to explain.

Galaxy clusters merging and releasing X-ray energy

There are other problems with the big bang model, such as the lack of antimatter in the universe. You probably have heard of antimatter in the context of science fiction, but antimatter is real. When matter and its counterpart of antimatter meet, they annihilate one another in a burst of energy (following Einstein’s famous $E = mc^2$ equation). The big bang model requires that the universe began with equal amounts of matter and antimatter, but clearly the universe is dominated by matter, so what happened to the antimatter? There is no satisfactory solution to this problem.

By the 1970s, cosmologists understood that there were two other problems with the big bang model — the horizon problem and flatness problem. In the 1980s, cosmologists invoked cosmic inflation to solve these problems. Inflation is a hypothetical rapid expansion that began and ended in the early universe, before the universe was 10^{-32} seconds old. Inflation supposedly was far faster than the speed of light. No one knows what caused inflation, or what caused it to stop. Nor is there any evidence for inflation. However, cosmologists and astronomers generally believe inflation happened, or else the universe that we know wouldn’t be here. It doesn’t occur to most of them that perhaps the big bang model is wrong.

Age, Origin, and Fate of the Universe

Within the big bang theory, cosmologists use the Hubble constant, H, to estimate the age of the universe. To a first approximation, the age of the universe is the reciprocal of H. We call this the Hubble time, $T_H = \frac{1}{H}$. Notice that H has the units $\frac{\frac{km}{s}}{Mpc} = \frac{km}{s}$ Mpc. Since both km and Mpc are units of distance, then H has units of reciprocal time. Therefore, the reciprocal of H has the units of time. To determine the value of the Hubble time, we must convert km to Mpc or Mpc to km. Since the Hubble time is so large, it helps to convert T_H from seconds to years as well. If $H = 50 \frac{\frac{km}{s}}{Mpc}$, then $T_H = 20$ billion years. If $H = 100 \frac{\frac{km}{s}}{Mpc}$, then $T_H = 10$ billion years. The currently accepted value of H is $70 \frac{\frac{km}{s}}{Mpc}$, which results in a Hubble time of 14.3 billion years.

Assuming a big bang universe that has been expanding at the same rate since its beginning, then the Hubble time is the age of the universe. However, there are reasons to believe the expansion rate has not been constant. For instance, the universe contains matter, which produces gravity. As the universe expands against gravity, the expansion slows. This is like an object launched upward from the earth. As the object climbs, it gradually slows. Most objects move slowly enough that gravity eventually reverses their upward motion. This can happen to the universe as well, but most cosmologists consider this unlikely. If we factor in the effect of gravity, we find that the universe was expanding more rapidly in the past. This means that if we find the Hubble time using the current value of H, our T_H will be too large. In other words, the Hubble time is an upper limit to the age of the universe.

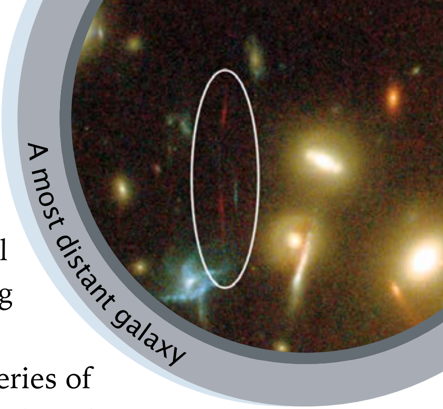
There may be other factors at work. We previously discussed why Einstein introduced the cosmological constant, an idea that soon was discarded, only to be revived at the end of the 20th century and rechristened *dark energy*. Both the cosmological constant and dark energy would cause the space of the universe to repel itself, resulting in accelerated expansion. Dark energy has the opposite affect that gravity has upon the age of the universe. Whereas gravity makes the universe younger than the Hubble time, dark energy makes the universe older than the Hubble time. The current thinking is that gravity has the stronger effect, shortening the age of the universe from the Hubble time. In 2004, a group of researchers concluded that the most probable age of the universe is 13.7 billion years (± 1%). However, a few years later this was revised to 13.8 billion years, the currently believed age for the universe. This value almost certainly will change again.

What is the origin of the big bang universe? As we discussed elsewhere in this chapter, some people see God in the origin of the big bang. However, most cosmologists attempt to explain the universe in terms of some sort of natural phenomenon. One explanation is that the universe began in a quantum fluctuation. Quantum fluctuations are small, hypothetical violations of the conservation of energy that happen for very short intervals of time. This is the result of the uncertainty principle in quantum mechanics, the physics of the smallest systems, such as atoms. The larger the violation of the conservation of energy, the shorter time that the violation can last. Presumably, if the energy involved is identically equal to zero, then the violation could last forever. There is much energy in the universe, so how could the energy of the universe be zero? Theorists have devised ways (all hypothetical) that the total energy of the universe might be zero. If the universe has zero total energy, then they reason that the universe merely could be a quantum fluctuation, an accident. As one theorist quipped, "The universe is just one of those things that happens from time to time."

There are other attempts to explain the universe physically. One suggestion is that there are many universes, a *multiverse*, if you will. From time to time, each universe within the multiverse gives rise to new universes. Therefore, our universe was spawned by some pre-existing universe of which we have no knowledge, just as our universe produces new universes of which we have no knowledge. The great British astrophysicist Stephen Hawking (1942–2018) has suggested that our universe is unbound in time. By this, he means that the universe has always existed. The big bang is just the most recent step in the evolution of the universe. However, we cannot probe beyond the limit of the big bang in the past.

You may find these suggestions humorous, but make no mistake — their proponents are very serious. These attempts to explain the origin of the universe illustrate several things. First, they illustrate that the ultimate question about the origin of the universe is not a scientific question. Indeed, the origin of the universe has no physical explanation, so we cannot study it scientifically. Second, they illustrate the atheistic philosophy that most big bang theorists adopt. Some scientists who are Christians claim that the supposed science of the big bang ultimately leads to God. However, the desperate attempts of cosmologists to explain the universe apart from the supernatural show otherwise.

What is the fate of the big bang universe? Theoretically, there are two basic possibilities. One possibility is that the universe eventually will slow its expansion and reverse into contraction. Some have suggested that the contraction will end in a "big crunch," from which the universe will rebound into a new big bang. This represents a complete return to the eternal universe, because then our big bang universe might be just a single episode of an infinite series of expansions and contractions. The other possibility is that the universe will expand forever, gradually getting cooler and less and less dense.


A most distant galaxy

Which scenario for the future of the universe is correct? Cosmologists think that they can determine which one is true by studying the universe. One critical factor is the amount of matter in the universe. If the universe contains at least a certain critical density, then the universe will eventually contract. If the universe contains less than this critical density, the universe will expand forever. Since about 1960, astronomers have measured the density to be less than that required to re-collapse the universe. Recent measurements of dark matter have increased the amount of matter, but it still is less than the critical density. If one adds dark energy, the chance of re-collapse is even more remote. Therefore, the best evidence is that the universe will expand forever.

As the universe expands, stars will gradually die out. The universe will expand until the density and temperature fall toward absolute zero. This is a very bleak outlook for the universe. The universe may have been born in a big bang, but it apparently will end in a whimper. Of course, this is in stark contrast to the Bible. While many Christians see the big bang in the Genesis creation account, many, including the author of this book, do not. Furthermore, the Bible, as in 2 Peter 3:10 speaks of the heavens passing away rapidly and violently. Instead of a gradual heat death, we know from the Bible that the universe will end in judgment, but that God will replace it with a more glorious new heaven.