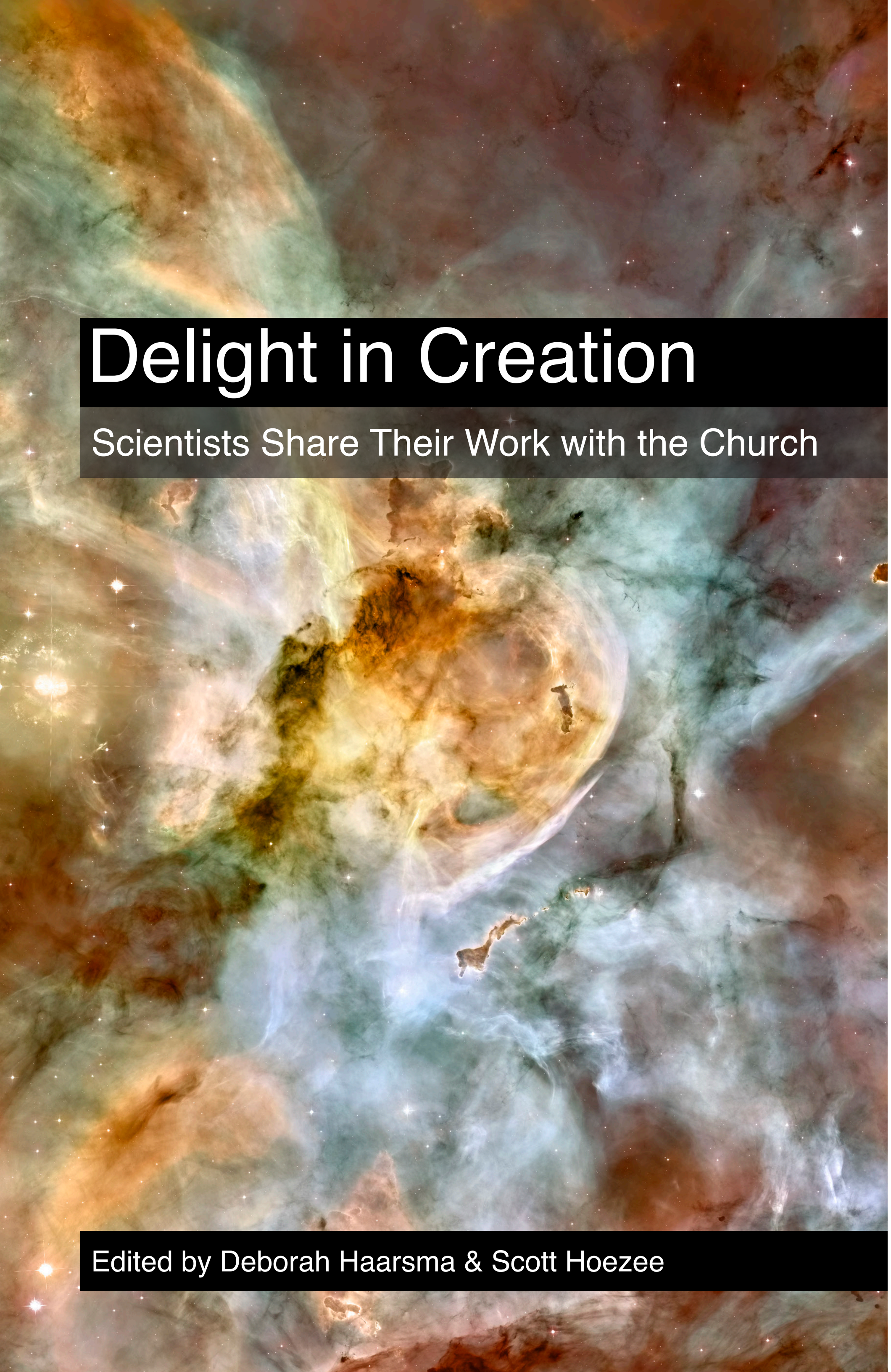

13 Universe and Multiverse

by Gerald Cleaver

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Called to Christ and to Science

By the time I was ten years old, I was already determined to follow a career in physics and cosmology, both because of the wonder I felt for the natural world and as a means to better resolve serious questions that were developing within me regarding the relationship between biblical interpretation and scientific discovery. The prior year I had read and studied scripture in its entirety for the first time, rather than just the piece-meal sections covered in my Sunday school classes. Whenever I look back at that year in my life, I am always glad I chose to study the New Testament before the Old Testament, rather than vice versa. From the New Testament study, I found salvation and accepted Christ into my life. But my examination of the Old Testament that followed raised serious questions for me, particularly regarding Genesis. Even as a ten-year-old, I could see the apparent conflict between Genesis and what I had already learned about the history of the universe, of earth, and of life on earth as reported by science. From science I felt amazement and wonder toward God as Creator and strongly desired to learn more about the physical laws set up by God that sustained the universe. In contrast, both of the Genesis stories of creation seemed simplistic and hollow.

As I continued to study, I came to believe that divine inspiration of scripture does not exempt scripture from portraying human authors' limited (in particular, finite) understandings of the physical world.

Since Genesis 1 and 2 were written in a pre-scientific age, we should expect a non-scientific description of the creation process. Divine inspiration allowed the language of the time to express eternal truths regarding some aspects of God's nature as Creator. Using stock images from the culture, the opening chapters of Genesis describe God as the ultimate Creator of all things and in charge of all things. These chapters should not be misinterpreted as scientific treatises describing the actual physics processes by which God creates all things.

From further study I came to understand that for almost two thousand years, many others far more knowledgeable than I had wrestled with the same issues. I was thrilled to learn that the early church fathers had developed a procedure for dealing with disagreement between scripture

and scientific understanding. In 1657, the famous scientist, mathematician, and devoted Christian, Blaise Pascal, summarized the procedure of St. Augustine and Thomas Aquinas in his *Provincial Letters*:

> When we meet with a passage even in the Scripture, the literal meaning of which, at first sight, appears contrary to what the senses or reason are certainly persuaded of, we must not attempt to reject their testimony in this case, and yield them up to the authority of that apparent sense of the Scripture, but we must interpret the Scripture, and seek out therein another sense agreeable to that sensible truth.… And as Scripture may be interpreted in different ways, whereas the testimony of the senses is uniform, we must in these matters adopt as the true interpretation of Scripture that view which corresponds with the faithful report of the senses.…
>
> An opposite mode of treatment, so far from procuring respect to the Scripture, would only expose it to the contempt of infidels; because, as St. Augustine says, "when they found that we believed, on the authority of Scripture, in things which they assuredly knew to be false, they would laugh at our credulity with regard to its more recondite truths, such as the resurrection of the dead and eternal life." "And by this means," adds St. Thomas, "we would render our religion contemptible in their eyes, and shut up its entrance into their minds."

During my teenage years, my conviction that science could be used to inform scripture and clarify our understanding and interpretation of it continued to solidify. I agreed with Galileo that "the Bible tells us how to go to heaven, not how the heavens go." Further, since God is the creator of all things, the physical and the spiritual, I came to understand that science as the study of the physical and theology as the study of the spiritual must be mutually consistent when both are properly understood. Inconsistency could only be the result of human misunderstanding of one or both arenas of knowledge. (Some might correctly point out that science is not always as clear cut as reason plus the report of the senses. That is, at times science also involves debates between competing interpretations, especially on the cutting edge of research. Nevertheless, ongoing scientific investigations gradually winnow away many or most proposed scientific descriptions of a given physical process, leaving only one or a few as the viable candidates. Scientific theories are formed by the general consensus of the scientific community based on overwhelming supporting physical evidence.)

In high school, I faced a serious medical problem, eventually identified as a brain tumor. Surgery was successful, in part due to a positive change in the tumor. In thankful response to God, I decided to pursue a career in church ministry. I determined a primary goal of my ministry would be to help the members of my future congregations develop mutually consistent and mutually supportive understandings of scripture and of science. I chose to attend Valparaiso University in Indiana, where I could, in addition to being a pre-seminary student, also double major in physics and mathematics to increase my scientific knowledge. Over the course of my four years at Valparaiso, I realized that my calling wasn't for a church ministry, but one aspect of it would be to minister to Christians as a professional scientist, demonstrating by example that faith and science need not be at odds.

Thus, by way of a curved path, I did indeed follow the vocation I had initially chosen twelve years earlier. I decided once again to pursue the path that made my heart sing: studying the underlying laws and forces of the physical universe. As I was deciding which Ph.D. programs in elementary particle physics and cosmology to apply to, I became aware of a new, quickly developing subfield of particle physics called *string theory* that offered the possibility of unifying all of the known forces and matter in the universe into a single theory. I am now a successful scientist in this area, publishing discoveries that add to our understanding of particle physics and the universe.

Advice for Christians

My path to a Christian vocation as a scientist is not unique. While each of our lives is different, I know from conversations with numerous Christian colleagues that they faced similar quandaries regarding apparent conflicts

between scripture and science. In many Protestant churches I have encountered Christians who fear science because of this seeming conflict. On the other hand, I have also encountered Christians with a desire to better understand modern science and its interplay with scripture, but little opportunity to do so. Likely there are some scientists or young people in your congregation dealing with similar issues.

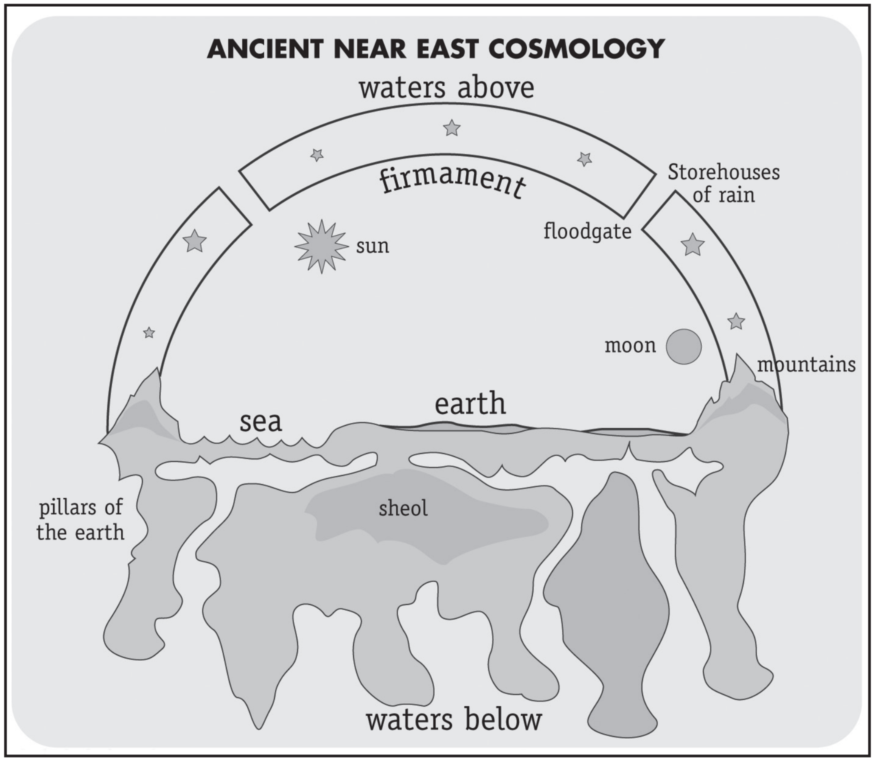
I encourage churches to develop and teach a consistent Christian worldview in which scientific and theological understandings of the universe are viewed as mutually supportive and complementary. The historic "two books" view of nature and scripture reminds us that God's revelation comes not just through the Bible, but through the physical world as God's book of general revelation to us. In line with Augustine, Aquinas, and Pascal, we must not reject outright the testimony of scientists, since they speak truths about God's creation. Nor can we afford to ignore the controversial aspects of this debate. Churches should instead invite scientists who are Christian to share their knowledge with the congregation and come alongside them to wrestle with difficult passages. Churches can lead in-depth studies of the scriptures, helping everyone to better understand the historical aspects and cultural milieu of the text. Often a misunderstanding of the context can create a false conflict between scripture and science.

Churches can also remind Christians of the many ways that science enhances faith. Learning about science and scientific discovery can deepen our understanding of God's creation and of God's creative nature. It can renew and deepen our awe and reverence for God. Science can also shed new light on scripture and on theological issues. In the rest of this essay, I want to share with you the beauty, order, and wonder of creation displayed in my own field, elementary particle physics and cosmology. In order to understand these discoveries, I will start with a brief history of the human views of the universe.

Expanding Views of the Universe

Over the last few thousand years, the human perception of physical reality has gone through several stages. Each shift has illuminated a larger, grander creation, and for Christians, each advance should signify a fuller representation of God's eternal power. The Middle Eastern world of one to two millennia B.C. perceived reality essentially as a three-tiered structure (Fig. 1). Center stage was the flat surface of the earth and the ground below containing the underworld of the dead (e.g., the Sheol of the Old Testament). Beneath this level was a primeval ocean upon which the earth floated and into which the pillars of the earth descended. Far above were the split levels of the heavens: the firmament of the stars and the sun and moon and the watery expanse of the heavens kept separated above by a cover (as in Gen. 1:7), and often beyond that was the heaven of heavens. This was the setting in which Genesis 1 was written.

FIGURE 1. *Three story paradigm of the Ancient Mideast world.*



TAKEN AND REPRINTED WITH PERMISSION FROM ORIGINS: CHRISTIAN PERSPECTIVES ON CREATION, EVOLUTION, AND INTELLIGENT DESIGN (C) 2011 FAITH ALIVE CHRISTIAN RESOURCES.

IMAGE CREDITS: VICTORIA SEABURG FOR THE MINISTRY THEOREM, AFTER WIKIPEDIA COMMONS DIAGRAM

FIGURE 2. *Geocentric paradigm of Greco-Roman era to 1600's.*

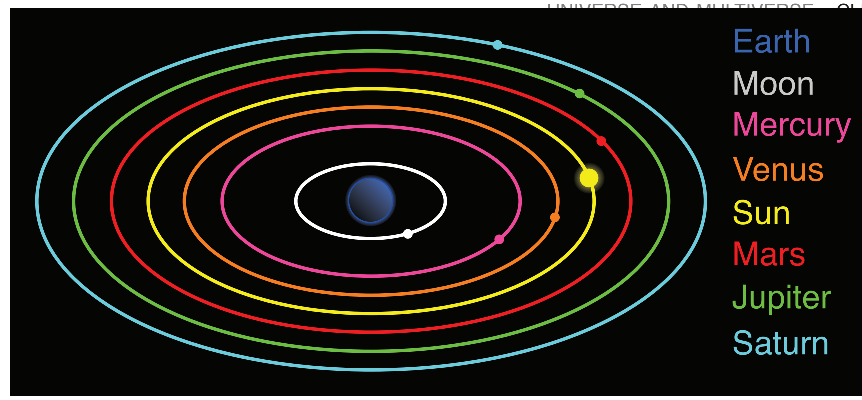
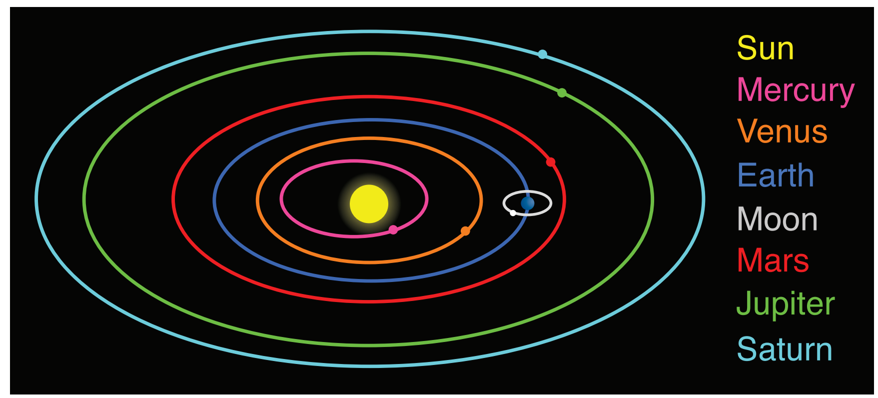


FIGURE 3. *Heliocentric paradigm of the 1600's through 1700's.*



The Greek civilization brought about a significant paradigm shift, one that lasted almost one and a half millennia—the *geocentric* picture, in which both the sun and the other planets were believed to orbit around the earth (Fig. 2). Then, in the 1600s astronomical discoveries by scientists such as Galileo resulted in the realization that the earth and all of the rest of the planets orbit the sun. Thus was born the *heliocentric* era. Simultaneously, the law of gravity was developed by Isaac Newton and proven to apply both on the earth and throughout the whole heliocentric system (Fig. 3).

IMAGE CREDIT: HUBBLE HERITAGE TEAM

FIGURE 4. *Galacticentric paradigm of 1800's through early 1900's.*

By the 1800s, astronomers discovered the existence of gaseous nebula beyond the solar system and found that our sun was but one of hundreds of billions of stars within the so-named Milky Way galaxy. Thus, a *galacticentric* perception replaced the heliocentric (Fig. 4). Our galaxy and its contents were believed to compose the entirety of the universe.

By the 1920s, many of the objects identified during the preceding century as "spiral nebulae" inside our Milky Way galaxy were discovered by astronomers such as Edwin Hubble to be independent galaxies, located vast distances (millions to billions of light years) away from the Milky Way and of comparable size to it. Thus, after little more than a century the galacticentric paradigm was transformed into a *univercentric* paradigm, with our universe comprising the entire stage (Fig. 5). Over the following decades, around a trillion visible galaxies were identified in our visible universe, each possessing hundreds of billions to trillions of stars.

FIGURE 5. *Univercentric paradigm of 1920's through early 2000's.*

IMAGE CREDIT: NASA, ESA, S. BECKWITH (STSCI) AND THE HUDF TEAM

FIGURE 6. *Computer generated 3-dimensional picture of visible universe.*

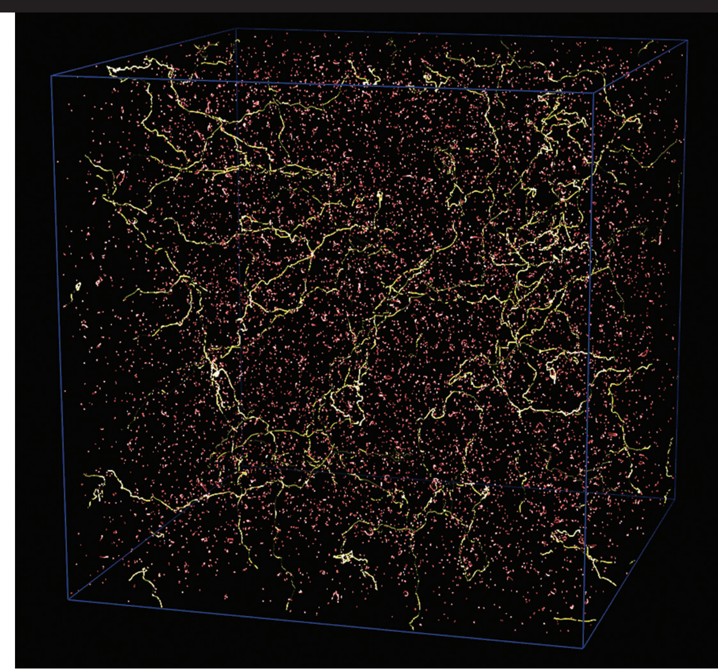
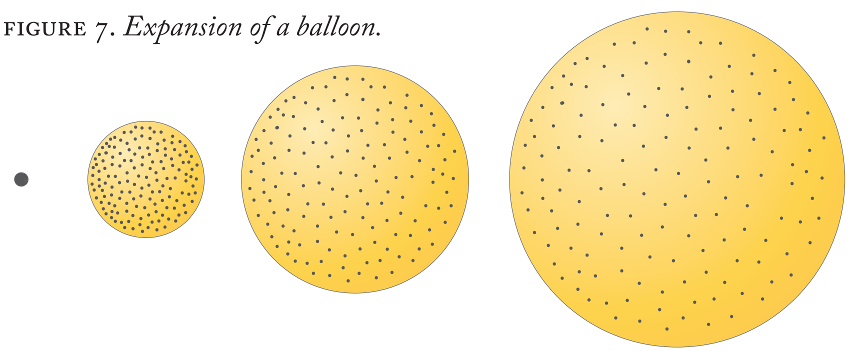


IMAGE CREDIT: CAMBRIDGE COSMOLOGY GROUP

Evidence for the Big Bang

The univercentric paradigm naturally raised the question, "How came the universe?" Not only does modern science show us the extent of the universe, but its understanding of the history of the universe is also highly detailed and exact. In 1929, Edwin Hubble proved that the universe was expanding. By observing distant galaxies and the light they emit, he showed that the further away a galaxy was from ours, the more rapidly it was moving away from it. As an analogy, consider a spherical balloon being blown up (Figure 7). The dots on the surface of the balloon are analogous to galaxies, and the inflating balloon is analogous to the stretching of space between the galaxies. An observer on any one of the dots would perceive the other dots to all be moving away from him at rates proportional to their distance away.

FIGURE 7. *Expansion of a balloon.*



This expansion means that in the distant past the universe was much smaller than it is today. So, following Hubble's discovery, scientists began to consider a model in which the universe started out extremely small, with all of the matter packed close together. Near the very beginning, the entire universe would have been extremely hot (at least 10^{32} degrees) and extremely small (10^{-33} cm, which is much smaller than an atom, in fact 1/10000000000000000000 times smaller than the tiny nucleus inside an atom). This model was called the *Big Bang*. Although some people use the term "Big Bang" as if it were a replacement for God, it is merely a scientific explanation of how the universe developed after the first instant (immediately after time t = 0).

The Big Bang was confirmed by several independent pieces of evidence. The first and best known is the verification of a specific Big Bang prediction, that the heat of the early universe should still be visible today as low energy radiation from all over the sky. This radiation was discovered unintentionally by two IBM employees in 1963.

Several independent lines of evidence point to billions of years of history since the Big Bang. Astronomers understand much of this history and have found no serious gaps, other than what happened to start the Big Bang. I understand this detailed history of the universe as the ongoing process by which God continually creates the universe.

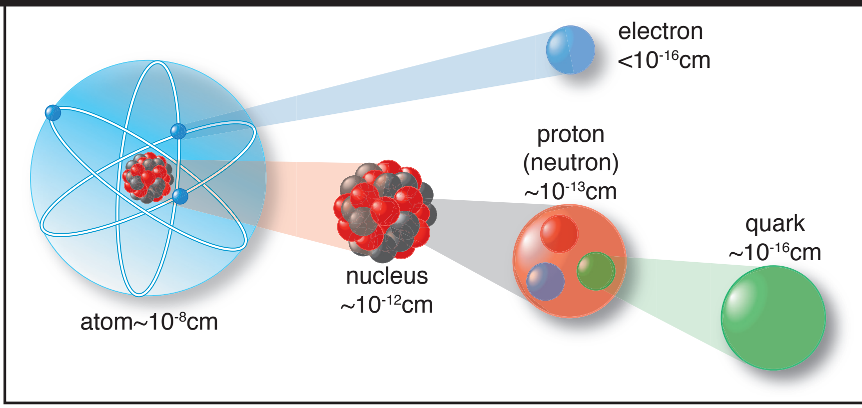
Forces and Particles

Parallel to the development of modern cosmology in the twentieth century, physicists began a concerted drive to understand the forces of nature in a consistent, interrelated manner. Long before this, in 1687, Newton had worked out a basic understanding of the force of gravity. Two centuries later, in 1864, James Clerk Maxwell derived the fundamental equations of electromagnetics, thereby proving that electricity and magnetism were manifestations of a second force, one associated with light. From then until the 1930s, gravity and electromagnetics were believed to be the only forces. But with the discovery of the neutron in 1932, physicists learned of additional forces (what became known as the strong and weak nuclear forces). Although the first attempts to explain the strong nuclear force appeared in 1935, the first true models of the nuclear forces did not develop until the 1950s. Then in the 1960s, a way to combine electromagnetism with the weak nuclear force was discovered and referred to as *electroweak theory*. Simultaneously, understanding of the strong nuclear force was accomplished during 1963 to 1965. The related theory was named *quantum chromodynamics* (QCD). These theories showed that all the fundamental forces (with the exception of gravity) were related.

As the understanding of forces developed, physicists were also learning about the elementary particles that compose all matter. Around 1870, the periodic table of the elements was developed by Dmitri Mendeleev and others as a systematic way to organize the dozens of known atoms; today

117 types of atoms are known. In the early 1900s, physicists discovered that each atom is not solid like a billiard ball, but is made of more fundamental particles: protons and neutrons in a nucleus with electrons swirling around the nucleus.

FIGURE 8. *The particles inside an atom.*



Yet the protons and neutrons are still not the most fundamental; high-speed collisions in particle accelerators hinted at the existence of even more elementary particles. Experiments also began to reveal many particles besides protons, neutrons, and electrons. For a time, physicists were discovering new types of particles faster than they could explain them—there seemed to be a "zoo" of particles rather than orderly categories.

Gradually a more orderly picture came together. Protons and neutrons were each discovered to be made of elementary particles called "quarks." The two most common types of quarks are called *up* and *down*, and come in three varieties (called *red*, *green*, and *blue*). When you add in the electron and the electron neutrino, you get a family of eight elementary particles. All of the atoms in the periodic table can be explained with just those eight particles. That's a lot simpler than 117!

Physicists also found that associated with each of these eight particles is an *anti-particle*. Anti-matter is commonly referred to in science fiction, as in *Star Trek*, making it sound very exotic. Yet the essential difference

between anti-matter and regular matter is just the sign of the electric charge: if a particle is positively charged, its anti-matter partner carries a negative charge (or vice versa). The existence of anti-particles doubles the number of elementary particles in a family to sixteen.

As all of the elementary matter particles were discovered, physicists were also learning more about forces and discovered the existence of another category of particle: a "force-carrying" particle. This is difficult to picture, but you have already heard of one such particle, the photon. The photon is the force-carrying particle for electricity and magnetism. QCD is associated with eight force-carrying particles (called *gluons*, because like a glue, they cause quarks to stick together) and the electroweak force with four force-carrying particles (including the photon), making a set of twelve force-carrying particles (see Figure 9 on next page).

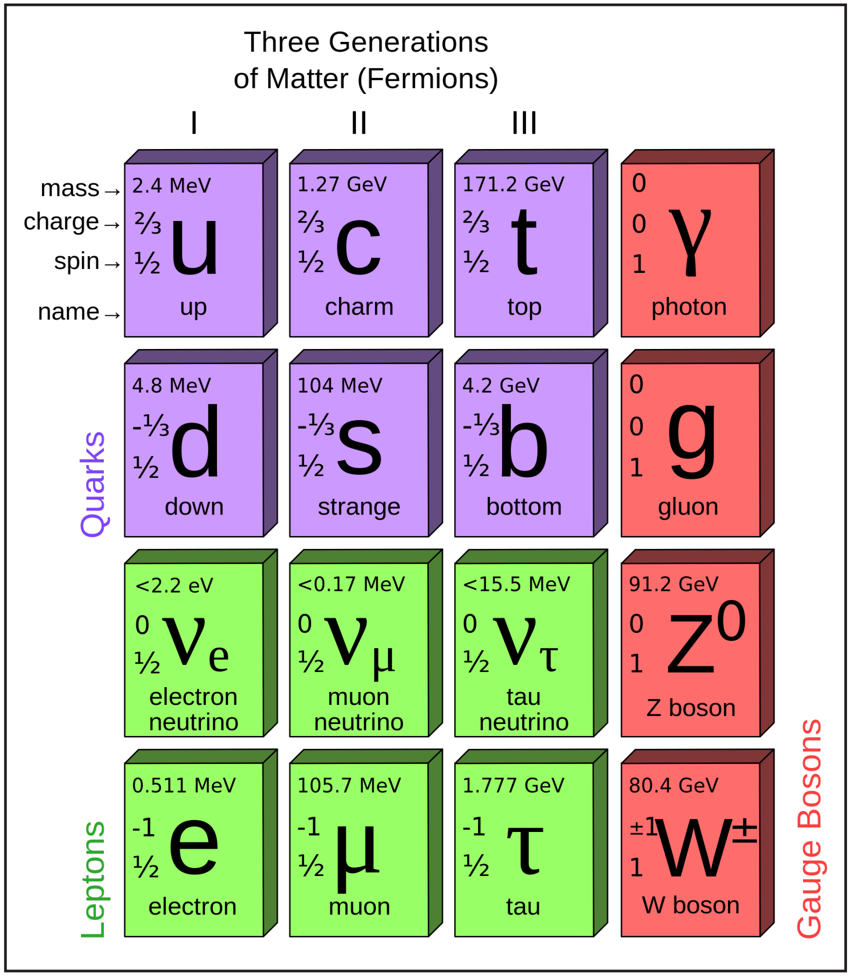
The Standard Model

This set of forces and matter particles became known as the *Standard Model* of Elementary Particle Physics. This includes the combination of twelve electroweak and QCD force-carrying particles, plus the sixteen particles making up ordinary matter. It also includes two additional exotic matter families, containing another sixteen particles each. Each particle in an exotic family is nearly identical to a corresponding one in the more ordinary first family of particles. The primary difference between the first family of particles and the exotic second and third families is that particles in the latter two families are more massive.

Two additional particles called the *Higgs* (named after the physicist who first theorized their existence) are also believed to exist and are included in the Standard Model. The two Higgs particles apparently give mass to all matter particles. They are expected to be produced at the Large Hadron Collider (LHC) at CERN, Switzerland, within the next few years. In total, the Standard Model contains sixty-two elementary particles.

Mathematical aspects of the Standard Model further suggest that each of these 62 elementary particles has associated with it another particle, called its *supersymmetric partner*. While none of these supersymmetric particles have been found to date at either Fermilab or CERN, if they exist,

FIGURE 9. *Three generations of matter particles and the force carrying particles.*



*The left three columns show three families ("generations") of matter particles (quarks and leptons, shaded purple and green). The right columns shows force carrying particles (bosons, shaded pink). In addition to the particles shown, each quark comes in three so-called colors (red, green, blue), and each of those has an antiparticle with opposite color (anti-red, anti-green, or anti-blue) and opposite electric charge. Each lepton also has an anti-particle of opposite electric charge. Thus, there are 16 = 2*3 + 2*3 + 2 + 2 matter particles in each generation. The force carrying particles also come in more varieties than shown (a total of 12).*

IMAGE CREDIT: WIKIPEDIA COMMONS

they should also soon be discovered. Their existence would increase the number of elementary particles to 124. This set of 124 particles is called the *Minimal Supersymmetric Standard Model* (MSSM).

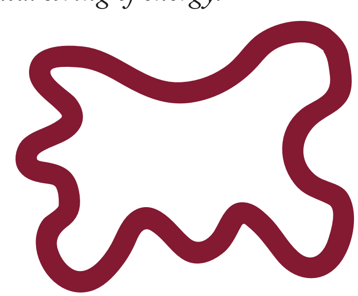
Beginning in the 1980s, some elementary particle physicists suggested that the Standard Model might not be the underlying fundamental theory. First, a theory with either sixty-two or 124 elementary particles doesn't seem that simple or fundamental, even if it is more orderly than the earlier "zoo." Also, why are there two exotic copies of the everyday set of sixteen particles? There is also no explanation why QCD or the electroweak force took the respective form that each did. Further, neither the Standard Model nor the MSSM offers a connection between these forces and gravity.

String Theory: One Particle and Ten Dimensions

A possible resolution to the Standard Model issues first appeared in the mid-1980s and is called *string theory*. It is a theory that unifies the strong and electroweak forces of the Standard Model, while it simultaneously *reduces* the number of elementary particles from 124 to 1. This is an amazing accomplishment—it offers the possibility to finally achieve the "holy grail" of physics, to unify all the forces into a single picture (sometimes nicknamed the *Theory of Everything*, but better called the *Theory of Everything Physical*). String theory simplifies the understanding of particles by showing that all particles are fundamentally the same and have the same origin.

According to string theory, there is only one fundamental particle from which both force-carrying particles and matter particles are formed. This particle is essentially a *closed string* (or *loop*) *of pure energy* (Fig. 10).

FIGURE 10. *Fundamental string of energy.*



The string is tiny with a length of 10^{-33} cm (recall this length was discussed prior—the universe started out no larger than this size). The string of energy can produce all the other particles by vibrating in different ways. Just as vibrations travel up and down on a violin string, so vibrations travel around the string of energy. A violinist changes the way the violin string vibrates in order to produce a different musical note. Similarly, when the vibration of the string changes, the string appears as a different type of *particle*. There are many ways the energy string can vibrate, including all sorts of combinations of clockwise and counter-clockwise vibrations—in fact, enough different combinations of vibrations to explain all of the elementary particles in the Standard Model.

Thus, string theory solves several difficulties of the Standard Model. But it does much more. It opens new vistas in our understanding of nature, including multiple universes (discussed further in this essay) and whole new dimensions of space in our universe. Our everyday lives exist in three spatial dimensions (height, width, depth) and one time dimension. We can speak of these together as *spacetime* and say that we live in 3+1 spacetime dimensions. In order for string theory to be mathematically consistent, however, spacetime instead must be exactly 9+1 dimensional. That is, six additional spatial directions beyond height, width, and depth must exist! Since we can only perceive the spatial dimensions of height, width, and depth, scientists immediately realized that these extra dimensions must be very small (referred to as *compact*). Not only are the extra dimensions much too small to see, they are much smaller than an atom. In fact they are of the same length scale as the string itself, that is, around 10^{-33} cm. These compact dimensions differ in another way from the three large dimensions we are used to: they are *closed*. This means that in moving along a compact direction, you would return to the starting point after traversing a distance of only 10^{-33} cm. Picture an infinitely long rope (Figure 11). A tightrope walker can travel infinitely far along the long direction of the rope (like one of the three large dimensions), but a small ant crawling around the circumference of the rope will quickly return to where it started (like one of the six compact dimensions).

Astonishingly, the existence of these compact directions is the reason that all forces and matter are related. In fact, without compact directions,

FIGURE 11. *Example of a compact dimension.*

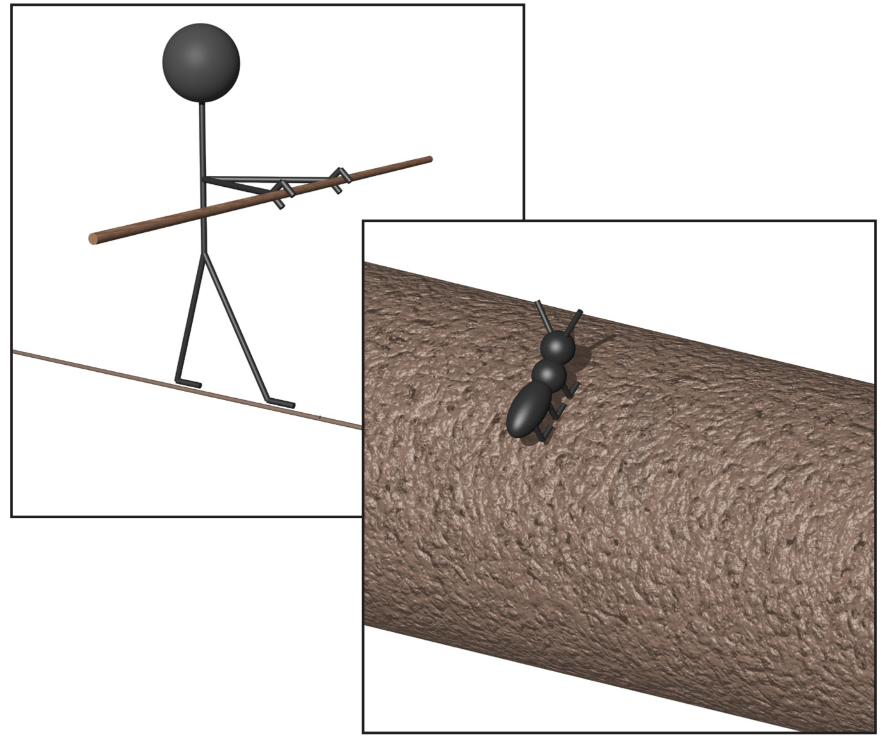
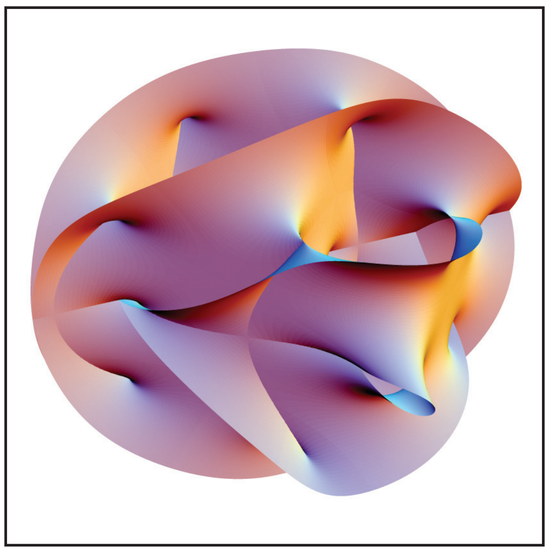


IMAGE CREDIT: DR. STEUARD JENSEN, ALMA COLLEGE

the types of particles in string theory would be vastly reduced to only those that carry the gravitational force. That's because such particles involve vibrations only in the three large spatial directions. The electroweak and strong force-carrying particles are produced when the vibration is also in the compact directions. Matter particles are produced when the string vibrates *only* in the compact dimensions. Thus, in string theory, without extra compact spatial dimensions, the matter particles making up our bodies (and all other objects) could not exist. This is a stunning conclusion: although we exist in the three large dimensions, each elementary particle in our bodies is a tiny energy string vibrating in extra compact spatial dimensions!

In addition to automatically producing all of the forces and all of the matter particles, string theory also explains why they have their specific properties. On a violin, the length of the string and the shape of the soundboard determine what vibrations are possible and thus what musical notes can be played. In string theory, the size and shape of the six compact dimensions determine what vibrations the string can have and thus what particles are produced. Therefore, *the shape of compact space itself* determines the types of matter particles allowed and types of the non-gravitational forces. Much of the work of string theory involves figuring out how the six compact dimensions might be shaped. It turns out there are around 100 trillion (very complicated) possible shapes, called *Calabi-Yau manifolds* (Fig. 12). A primary effort of string theorists was to determine which of the 100 trillion Calabi-Yau shapes for the extra six compact directions corresponded to the space of our universe. If the correct compact shape could be found, string theory had the potential to be the actual Theory of Everything (Physical). A handful of Calabi-Yau shapes were eventually found that came very close (but not exactly) to producing exactly the forces and matter particles of this universe. This search continued full scale for roughly a decade, with significant progress made in some cases.

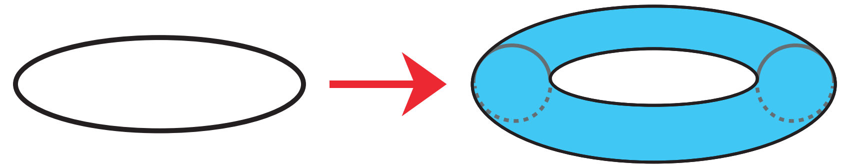
FIGURE 12. *Example of a Calabi-Yau manifold.*



This is the likely shape of the compact dimensions. Only 2 dimensions are shown, rather than all 6.

IMAGE CREDIT: WIKIPEDIA COMMONS

FIGURE 13. *Fundamental particle discovered to be a Torus, not a String.*



Eleven Dimensions and Multiple Universes

However, an underlying nagging issue of string theory was that it wasn't actually a single theory, but five alternative theories. In each theory, the energy string possessed slightly different properties. Was one theory better than the other four? No one could determine the answer, so string theorists investigated all five theories—that is, until 1994 when a group of string theorists proved that all five theories were actually identical, with equivalent physics expressed by different mathematics. This was like finding five copies of the same book, but written in five vastly different languages, such as English, Russian, Hebrew, Mandarin, and Swahili. If a person couldn't read more than one of the five languages, he or she would likely assume all five books were different. But one who knows all five languages would instantly recognize that all five books tell the same story. And so it was with the five "different" string theories.

Around 1995, a mathematical "Rosetta Stone" was found that translated between the five theories. This discovery had an unexpected implication: it revealed that the fundamental particle of the theory wasn't energy trapped in the shape of a string, but actually energy trapped in the shape of a torus (or donut)—which is a closed string with thickness (Fig. 13). Replacing a string with a torus required for mathematical consistency of the theory an increase in the number of spatial directions from nine to ten. And increasing the number of spatial dimensions came with even further unexpected and more profound implications.

First, the number of possible shapes of compact dimensions to be investigated increased from a "mere" 100 trillion to *at least* 10^{500} (that is a one followed by five hundred zeros). This meant that finding the one shape that exactly describes our universe became exceedingly more difficult (essentially impossible). But that was trivial compared to a second discovery that carried deep philosophical and theological impact. While the original 9+1 dimensional string theory was consistent with the existence of a single universe (that was initiated by a standard Big Bang), the enlarged 10+1 dimensional theory is not. Instead, the 10+1 dimensional enlarged theory implies that not just one universe is created at a time, but that on the order of *at least* 10^{500} universes will likely be created simultaneously, each with *different, distinct physical laws*. Our universe, enormous as it is, is likely merely one of a vast, almost uncountable, number of universes.

Instead of a standard Big Bang producing one universe, about once every hundred billion to trillion years a new set of around 10^{500} universes is likely generated by simultaneous Big Bangs. The new universes would take the place of earlier, preceding, universes, which likely reached either a Big Freeze or Big Burn conclusion. The set of all such universes over all time has been named the *multiverse*. The multiverse renewal process could continue indefinitely. The earliest models of the multiverse suggested the multiverse would be infinitely old, rather than have a distinct beginning. More recently, physicists have concluded that the multiverse cannot continue infinitely into the past. (Leaders in the field showed this discovery in a series of peer-reviewed publications.) Thus, the multiverse likely has an overall starting time, albeit hundreds of trillions of years ago. The time of the Big Bang of our universe is not the same as the starting time for the whole multiverse. Rather, the multiverse would have begun hundreds of trillions of years earlier.

If string theory in its extended 10+1 dimensional form is true, the universe in which we exist is likely not the only universe that arose 13.7 billion years ago. Rather, *at the beginning of our universe*, God also likely created far more universes than we could have imagined before. Many of these other universes might support life, but perhaps in vastly different forms than our atomic-based variety.

Theological Implications of the Multiverse

Some find the multiverse picture to be troubling, but I believe that string theory and its implied multiverse provide a much deeper understanding of the whole story of creation. With the multiverse, the human perception

of reality has expanded by previously unimaginable orders of magnitude. With the dawning of the multiverse paradigm, Christians are thus able to perceive the creative nature of God on a scale and vastness as never before. The emerging story also has profound implications for theological views of God, including the meaning of God's transcendence and immanence.

The historic Christian understanding of transcendence is that God is separate from his creation, this universe (including everything in it). That is, as Creator, he is beyond the spacetime of the universe. As St. Augustine described, God must in some sense "view" this universe in a four-dimensional block form, with all spacetime events appearing "simultaneously" in the same "picture." On the other hand, immanence implies that God is infinitesimally close to his creation and, further, through the second and third persons of the Trinity, is present within his creation.

To understand transcendence in the context of a multiverse, we must consider the concept of time within the multiverse. Each universe results from its own individual Big Bang and thus has its own concept of time as measured from within, independent and uncorrelated to the respective times measured within all other universes. Transcendence implies that God, as the Creator, must be beyond the spacetime of *each* universe within the multiverse. Further, there must also be some sense of overall global time in a multiverse frame from which specific times can be assigned for the series of Big Bangs. Thus, transcendence also implies that, as Creator of the multiverse as a whole, God must be outside of the space and global time of the multiverse. That it, God is necessarily beyond the *block multiverse*.

God's immanence within the multiverse also requires further theological contemplation, especially with regard to our understanding of the nature of the second person of the Trinity. What if God communicates with his sentient creatures in each universe through the advent of the second person of the Trinity in the physical form of the sentient creatures? Such theological considerations are not unique to the multiverse. Rather, the possibility of life within other universes in the multiverse and the theological implications are essentially many orders-of-magnitude extensions of the possibility of extra-terrestrial life within this universe and its theological implications. The Catholic Church in particular has contemplated the latter for several centuries. In fact, in the 1300s, it was declared a heresy to state that other worlds like earth *could not* exist elsewhere in the universe. By the 1600s, some Catholic priests proposed life elsewhere in the universe and contemplated the theological issues it raises. Pope Benedict XVI recently held an international conference at the Vatican on the existence of extra-terrestrial life, to which both leading scientists and theologians were invited. According to Brother Guy Consolmagno, who holds a M.S. from M.I.T. and a Ph.D. from the University of Arizona in planetary science, if new forms of life were to be discovered, it would not mean "everything we believe [theologically] in is wrong," rather, "we're going to find out that everything is truer in ways we couldn't even yet have imagined."

If string theory is proven correct, we may be nearing the next step in understanding the beauty, splendor, complexity, and vastness of God's creation—far beyond anything we could have imagined before. This multiverse paradigm shift would truly be of far greater magnitude and vastly more comprehensive than all of the preceding paradigm shifts. The science of today and tomorrow can, indeed, instill further awe and reverence for God, likely in ways unimaginable even a few decades ago.