# Coming of Age in the Milky Way Study Guide

## Coming of Age in the Milky Way by Timothy Ferris

# Contents

# Plot Summary

"Coming of Age in the Milky Way" by Timothy Ferris is fundamentally the history of astronomy and astrophysics. It is also the history of the universe as we know it up to this point in time. What is obvious throughout the book, is that the more man learns the more he knows about the universe and all its creations including himself is how much he really doesn't know. As twentieth physician Lew Thomas put it, "The greatest of all the accomplishments of twentieth-century science has been the discovery of human ignorance." Ferris takes the reader first through early man's reaction to the skies and the stars. Someone even as brilliant and learned as Aristotle thought there were two realms of the skies. His hypothesis was that there was a realm below the moon and one above it and that there was no great beyond because virtually nothing existed beyond it. To Aristotle, the stars were stationary objects in the upper realm.

Copernicus and Galileo adapted the theory that the earth was not the center of the universe that it was instead the sun that the earth was subservient to. There were such religious objections to such a theory that Copernicus was reluctant to share his theories and Galileo was arrested by the clergy for advancing them. The stories of these early astronomers is captured in Ferris' narrative as part of the story of man's relationship with the universe. He describes the struggles they had with other scientists, governments and the clergy. The book takes the reader through the advancements of modern classical physicists like Newton and Einstein who both changed the science forever and how mankind was positioned in the vast expanse of the universe.

Ferris describes how man sought answers to the mysteries of the universe right here on earth. Digging down to the strata, earth revealed just how old it was, once again arriving at a critical turning point in which science was conflicting with religion. The the ages of rocks verified through scientific carbon dating that the earth was much older than what was recorded in the Bible. But earth revealed much more than just its age. It uncovered important data about the universe. Scientists learned from Darwin's work that the elements that existed on earth and created life were those same elements that existed everywhere in the universe. Man's connection to the earth and the universe was without question.

The author takes the reader into the mysterious world of quantum physics where further evidence is provided that man is connected to the universe at its most miniscule and infant stages as evidenced in advancements made in the subatomic world. Modern physics proffers theories about how it all began and how the universe was created. But even at the conclusion of this coming of age story about mankind, there are more questions than answers. But there is hope that the intelligence of man will some day reverse the story's ending.

# Chapter 1: The Dome of Heaven

## Chapter 1: The Dome of Heaven Summary and Analysis

The ancient Sumerian, Chinese and Korean astronomers would climb to high elevations to get a better look at the stars. The Egyptians thought of the sky as a canopy supported by the mountains. While ancient cultures didn't understand the depth of space, they were aware of the motion of the stars and planets. The interest they had in the stars could be attributed to curiosity and some intrinsic need to be closer to the stars.

Practical reasons for learning about the stars and their movement included timekeeping and navigation. Early farmers used the sky as a calendar that told them when to plant and harvest. Stonehenge had its foundation in the skies. The Great Pyramid of Giza was aligned to a star. Various American Indian tribes marked the days of the lunar month.

But early astronomers found that the more they learned about the movement of stars and planets, the more complicated they realized the universe was. Some celestial objects stopped in their tracks and moved backward in retrograde. They weren't aware that the earth was also moving. The work of the early astronomers marked the beginning of the science of cosmology. One of the early astronomers was Eudoxus. In 385 BC, he attended Plato's Academy in Athens. Plato felt that "abstract geometrical forms were the universe" (p. 25). Plato wrote about the stars but seldom actually observed them.

Eudoxus studied with Plato then went on to establish his own observatory on the Nile where he designed a model of the cosmos. In 330 BC, with the conquest of Alexander the Great, the Greeks gained access to Babylonian astronomical records. Aristotle was also a devotee of stargazing. He created a model of the universe based on Eudoxus' work. Just as all the early astronomers, Aristotle's model placed earth at the center of the universe in what was a series of spheres. He did recognize that the earth was a sphere because of the shadow that it cast on the moon.

Claudius Ptolemy was a hardworking astronomer. He meticulously charted the stars from an observatory at Canopus, a city that was named for a star. His greatest work was entitled, "Mathematical Syntaxis" in which he accurately predicted the motions of the sun, moon and stars. But the Ptolemaic model was ungainly and was eventually looked upon as a mathematical fiction rather than an actual model of the universe.

# Chapter 2: Raising (and Lowering) the Roof

## Chapter 2: Raising (and Lowering) the Roof Summary and Analysis

Early models of the universe were diminutive in scale. The earth was portrayed as motionless and at the center of the universe as the stars and sun orbited them each day, which would have required the stars to travel at tens of thousands of hours a minute. The astronomers were convinced that the earth did not move because the citizens of Athens would have been thrown forward at thousands of miles an hour. These early cosmologists did not fully understand the concept of inertia and it would not be fully comprehended until the days of Galileo and Newton. Once it was theorized that the earth was orbiting the sun and spinning on its axis, the estimation of the size of the cosmos was greatly expanded.

Aristarchus was the first astronomer to suggest a solar-centered planetary system. He also estimated that there were much longer distances between the earth and the sun and moon. Archimedes wrote a paper entitled, "The Sand Reckoner," which described a system to deal with large numbers. He claimed that he could calculate how many grains of sand it would take to fill the universe. He used Aristarchus' model of the universe to make the calculation at 1063, which was greatly understating its size but overestimating its density.

By the time of Archimedes' death, Greek science, along with the rest of the intellectual world, had been transferred from Athens to Alexandria. Ptolemy I established a great library and museum where scientists could carry out their work and research. As the Romans completed their conquest of the known world, the emphasis was on law and technology but science was considered an art and was relegated to a lesser importance.

Two centuries after Jesus Christ who was sentenced the death by Pontius Pilate, Christianity became the state religion of Rome. However, the influence of Christianity did not elevate science since its focus was on asceticism, the after-life, and spirituality. After the fall of Rome, Christian zealots were said to have burned all the "pagan" books in the library of Alexandria and a mother-load of knowledge went up in smoke.

The pursuit of science fell to Islam and the Arabs who were intrigued by Ptolemy. An Arabic secret society known as the Brethren of Purity published tables of planetary distances that had been calculated by Aristarchus. The Islamic followers of Ptolemy misinterpreted his calculations and created a model that was cumbersome and impractical.

The last great Western scientist before the Dark Ages was Ancius Boethius who was an important figure in the court of Gothic emperor Tehodoric; but Boethius backed the losing side of a power struggle and was jailed and executed in 524. During the Dark Ages, few Western scholars held interest for math or science. Conservative churchmen looked at the universe in a spiritual sense. The planets were pushed around by angles, they declared, and Heaven was behind the sky and could only be reached through death.

# Chapter 3: The Discovery of the Earth

## Chapter 3: The Discovery of the Earth Summary and Analysis

The reawakening of interest in the cosmos was sparked by the age of exploration beginning with Marco Polo's travels to China in the thirteenth century and lasted through Columbus' discovery of America. There had long been a connection between the skies and the earth. Navigators had been steering their ships by the stars for centuries. Explorers of land used the stars as well to gauge their locations. American Indians lost in the woods could find their way with the help of Father Sky. As far back as Ptolemy, geography was employed as an aid in the study of astronomy. There was great incentive for exploring. European explorers were literally able to make fortunes by navigating their ships to the East. It was the explorer Marco Polo whose tales of the riches that could be had in the East that sparked this interest.

Sagres was the epicenter of the burgeoning interest in seaward adventures. Prince Henry the Navigator was the first to explore the coast of Africa and discover its rich natural resources. Henry's interest in sea travel and navigation led him to establish an astronomical observatory and navigational institute. It was an international organization that boasted Italian cartographers, German mathematicians, and Jewish and Muslim scholars. Based on the navigational guidance that resulted from the work done at the observatory, Henry dispatched dozens of expeditions down the coast of Africa.

In 1455, Venetian Alvise da Cadamosto who was one of Henry's ship captains, discovered the Southern Cross, six bright stars that appeared on the southern horizon. In 1488, Bartholomeu Diaz rounded the Cape of Good Hope on the southern tip if Africa. And ten years after that, Vasco da Gama reached India by traveling north from the Cape of Good Hope which ultimately opened up new and lucrative trade routes to the East. The Portuguese began importing gold and another source of revenue—slaves, over a million in all. The Chinese were also in the business of exploring Africa.

Christopher Columbus was an experienced navigator and, at times even a pirate on the high seas. Columbus was interested in reaching the East and in doing so was destined to find a New World. He persuaded Queen Isabella of Spain to finance an expedition. He was sure that the earth was quite small and by sailing west, he would reach the East with relative ease. He convinced the Queen that if he and his men sailed west, it would take them three years to arrive in India.

Columbus sailed in 1492 and attempted to keep track of time by the sun and the Little Dipper—although the number of days was miscalculated. He was able to navigate and make adjustments to his travels by following the North Star. On the night of October 12, 1492, Columbus and his crew spotted land which they believed to be India. Even on subsequent visits, Columbus was certain that he had reached India and threatened to hang any crew member who denied it.

One important aspect of the age of exploration was the awakening of man's imagination and his interest in learning about the planet and venturing to every corner of it. Some scholars of the Renaissance used their imagination to think of exploring space. Leonardo da Vinci imagined what earth would look like from the moon. Copernicus was a student at the University of Cracow when Columbus sailed into the West Indies.

# Chapter 4: The Sun Worshipers

## Chapter 4: The Sun Worshipers Summary and Analysis

Mikolai Kopernik was an astronomer and assisted his professor in Bologna in observing the sun and the stars. His worked proved that the Ptolemaic system was inaccurate. Kopernik loved to read and was born just thirty years after the printing press was invented. Kopernik benefited from reading the works of Plato, Aristotle, Archimedes and Ptolemy. Kopernik was born in Poland but studied in Italy and when he returned home he had changed his name to Nicolaus Copernicus.

Copernicus studied the great astronomers and particularly admired Ptolemy. His heliocentric theory corrected errors made by his idol. He was impressed by the logic of Plato's belief that there was an underlying structure to the entire universe which led him to believe that the sun was at the center of the universe. Copernicus was influenced by Parisian scholar Nicole Oresme who theorized that the earth was in motion.

Copernicus came to believe that the planets orbited the sun in perfect circles. Copernicus worked tirelessly for years trying to prove his theory. Most of his work was unpublished until his death because he feared retribution from the church. Even after his death, religious figures disputed his heliocentric model. Calvin accused him of thinking he was superior to God. Martin Luther cited the scriptures where Joshua "commanded the sun to stand still, and not the earth." (67)

Copernicus' book, "De Revolutionibus" published near the time of his death survived because it was too logical for scientists to ignore. One of the main achievements of Copernicus' work and writing was that it hinted at the immensity of space and provided a way to measure it. Aristotle's theory about the cosmos was that the stars were made of some element not found on earth which he termed "aether" and described it as ageless and unalterable. Aristotle separated the universe into two realms—the world below the moon and the unchanging world above. To Aristotle, comets were unexplained atmospheric phenomena. In 1577, Tycho Brahe, the foremost astronomer of the sixteenth century, proved the great philosopher wrong. Comets were not in earth's atmosphere—they were in outer space which destroyed Aristotle's theory that nothing in the upper universe moved.

More startling than moving comets was the supernova explosion that Tycho witnessed on 1572 also proving that things were not stationery in the skies above earth and that they certainly changed. There was another supernova in 1604 but the next observable one after that didn't occur until 1987. Tycho's meticulous observations proved the inaccuracies of the work of former astronomers including Ptolemy. Tycho was intrigued and having come from wealth was able to build a new observatory on the island of Sund. At the observatory, called Uraniburg, Tycho drove his staff as well as himself in pursuit of the most accurate observations possible with the constant charting of the positions of the stars. Tycho's model of the universe took a step back from Copernicus' heliocentric model. Although Tycho theorized that the planets orbited the sun but that the sun orbited the earth.

Tycho collaborated with astronomer Johannes Kepler who eventually discerned the accurate structure of the solar system and discovered the laws that govern the motions of the planet. Doing so he cleaned up the errors of former scientists including Copernicus. Kepler was inspired by the Pythagorean doctrine of celestial harmony referenced by Plato. Aristotle rejected the theory that the motion of the stars created a universal harmony. Churches and music of the time reflected the theory of a celestial harmony produced by the planets.

Above all, Kepler was a scientist and remained skeptical about all theories—including his own. Tycho and Kepler worked together but were often at odds. But Tycho could not afford to part ways with his younger, brilliant counterpart. When Tycho died, Kepler was named his successor. Kepler was never satisfied with his conclusions about orbits and focused much of his time and attention on correcting them. Eventually, he discarded the idea that the orbits were perfect circles around the sun; instead he concluded that they were actually perfect ellipses. Kepler published "The Harmonies of the World," the content of which became known as Kepler's laws. One revelation that a planet's speed increased as its orbit brought it closest to the sun. After Kepler and his family suffered from the wages of war, he died in 1630. His last words were about the skies above.

# Chapter 5: The World in Retrograde

## Chapter 5: The World in Retrograde Summary and Analysis

The work of Galileo Galilei during the Renaissance was a symbol of the importance of observation and experiment. Legend had it that he dropped two metal balls of different sizes off the tower of Pisa to illustrate that all objects fell at the same rate of speed. He did his work under much duress as he was persecuted by the Church for the conflicts his science had with religion. After studying medicine and loafing for several years, Galileo was appointed as a professor of mathematics at the University of Pisa and later a chair of mathematics at the University of Padua in Venice where he became a respected scholar and scientist.

Driven by debt, Galileo needed something to elevate his career from the ordinary to the extraordinary. It was then that he invented the telescope which was well-received in Venice, an unwalled city that could benefit from being able to detect enemies approaching from afar. Many Venetians earned their livelihood at sea where the telescope would obviously be beneficial. His invention was approved by the Venetian senators and was well-received. Galileo himself trained his telescope on the skies as opposed to approaching enemies on the ground. He saw the craters on the moon, Jupiter's multiple moons, and the moon-like phases of Venus. The greatest revelation from his observations was that stars were not fixed objects on the ceiling of the sky—there was depth to the sky and the stars were great distances away. Galileo published his findings in his "Sidereus Nuncius" or "Starry Messenger," which was read by people as far away as China.

As a physicist, Galileo attempted to bring physics into the discovery of the earth's movement. Contrary to Aristotelian physics, Galileo realized that when air was not a factor, a feather would drop as fast as a metal ball. He also advocated "thought" experiments. When experimentation wasn't possible, Galileo believed that reason could take over. It was through this thought experimentation that Galileo developed his laws of falling objects. Inertia or the resistance to change in motion was another consideration in Galileo's work. It was inertia and the density and mass of an object that defined the difference between a metal sphere and a feather. Aristotle declared that a body in rest tended to stay at rest. Galileo completed that theory by adding that a body in motion tended to stay in motion, especially the denser their mass was.

More would have been accomplished during this time had Galileo collaborated with Kelper but the two men didn't get along or see eye to eye on some of the issues. Galileo also struggled with scholars and the clergy in his attempt to convince them to adopt Copernican astronomy. The clerics were concerned about offending the All Mighty while the scholars were threatened by Galileo's intelligence and knowledge. He was warned not to press his theories too aggressively. But he was determined and it led to the Holy Office declaring Copernican science in conflict with the scriptures and Galileo was eventually arrested. An old man by then, Galileo begged for mercy and confessed the error of his ways. He spent the last eight years of his life in house arrest.

# Chapter 6: Newton's Reach

## Chapter 6: Newton's Reach Summary and Analysis

Isaac Newton developed a theory on gravitation and in doing so demolished Aristotle's dual universe and laid the groundwork for the Copernican theory of the universe. To this day, Newton's theories are solid and help guide spacecraft into deep space. Newton was an unusual person who searched for God all his life. His genius is obvious in the solutions as well as the questions he left behind. Although he was a scientist he was interested in alchemy and magic. In college he was a lone figure who spent his time reading the works of Plato and Descartes. He was intrigued by Descartes' theories on inertia and the solar system.

It was after college that Newton began to think that gravity existed on the moon and planets and that it kept them in place. It was Newton's development of the theory of gravitation that provided evidence that the physics of the heavens and earth were one in the same. Newton's first law expanded on the theory of inertia by asserting that an object stays in motion unless it is disrupted by another force. Newton accepted a position as a Lucasian Professor of Mathematics. As the years passed, Newton advanced calculus and geometry and studied alchemy. Newton's interest turned to the skies and he saw the need for a telescope that improved upon Galileo's refractor telescope. Newton invented a new telescope that employed a mirror rather than a lens for the collection of light. It was dubbed the "Newtownian reflector" and was effective and inexpensive to make and became the world's most popular telescope.

The Royal Society was established in 1603 with Edmond Halley, Christopher Wren and Robert Hooke as early members. Wren and Hooke were both astronomers and physicists. Hooke discovered the rotation of Jupiter. Halley, the youngest of the trio, was an astronomer and charted the southern skies. He also charted the movement of a comet that was named after him. The three men agreed that the inverse-square law could explain Kepler's discovery that planets moved in elliptical orbits; however, they found it difficult to prove with mathematics. Halley was certain that Newton would have the answer. Newton confirmed to Halley that the shape of the orbits was elliptical and that he had calculated the orbital path of the planets five years before. He shared his calculation with a grateful Halley.

Newton wrote a book on gravitation and the solar system called, "Mathematical Principles of Natural Philosophy and His System of the World," known as "The Principia" for short. It was his life's work and consumed all his time. The book was astounding in that it succinctly accounted for such a wide range of natural phenomena. He proved old theories wrong and revealed new ones including Newton's second law: force equals mass times acceleration ($F = ma$). Force resulted in an equal and opposite reaction. This law went a far way in explaining the motion of the planets. Newton's third law was that every action has a reaction.

# Chapter 7: A Plumb Line to the Sun

## Chapter 7: A Plumb Line to the Sun Summary and Analysis

Copernicus and Kepler measured the distances of the solar system which were expressed in astronomical units or the distance of the earth to the sun. However, the actual value of the astronomical unit had not been determined. There were two methods of determining those distances: micrometry and triangulation. Using micrometry, the astronaut used a micrometer, a device with a special eyepiece to measure the size of a planet as seen through a telescope. Triangulation to determine the parallax of a celestial object, was accomplished through the observation of a planet from two different perspectives on the planet. The data was then compared and calculations were arrived at through euclidean geometry.

Advancements were being made in both cartography and chronometry at a time when fortunes were being made at sea. But some ships and their crews were lost at sea because it was difficult to establish longitude—although navigators had long been able to determine latitude. Finding longitude had been an ongoing problem for so long that it was thought by many to be unattainable. But there was incentive to solve the problem with fortunes being offered by Spain, England and Portugal and other seafaring countries to the individual who could find the key to determining longitude.

John Harrison a carpenter turned clockmaker devoted his life to the longitude problem and as a result invented the marine chronometer which proved to be a very accurate longitude locator. With advancements in clocks and the development of better maps, astronomers attempted to triangulate the closest planets of Mars and Venus. Giovanni Cassini studied data by astronomer Jean Richer, who observed Mars at its closest passage to earth and determined, a value of 87 million miles for the astronomical unit. Since that time, astronomers have taken on the responsibility of observing the transiting planets and are able to predict when orbits will bring planets closet to earth.

One of the most renowned transit expeditions was launched by the Royal Society in August 1768 on the HMS Endeavour, which departed Plymouth for Tahiti to observe the transiting Venus. The ship was equipped with clocks, telescopes and meteorological equipment. Captain James Cook was an expert navigator and a self-taught astronomer. Although there were difficulties including the thick atmosphere around the planet, the data gathered by this expedition and others estimated the distance from the earth to the sun within 10 percent of accuracy. Further expeditions and triangulations of planets and stars began to reveal the enormity of the solar system.

English astronomer James Bradley calculated that the astronomical unit was between 93 million to 125 million miles. Later, Bradley used one star, Gamma Draconis, to establish an imaginary plumb line from the sky to the earth that could measure the star's shift. Bradley and his associates noted that there was a slight shift every day. It was

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later that Bradley figured out that the slight shift was not due to the star's movement but rather the earth's. It was obvious that more precise devices were needed to compensate for the earth's movement in the observation of transiting planets and stars. Telescopes improved and in December 1838, Friedrich Bessel used a precision telescope and successfully measured the parallax of the star 61 Cygni and was only ten percent off from the modern measurement. Thomas Henderson obtained the parallax of Alpha Centuri which is the closest star to the sun. The more that was learned about stars, the more curiosity grew about the make up and life of them.

# Chapter 8: Deep Space

## Chapter 8: Deep Space Summary and Analysis

Nebulae are fuzzy patches of glowing material that can be observed throughout the universe. Nebulae comprise three different classes of objects: gas thrown off by dying stars; clouds of gas illuminated by nearby stars; and, elliptical and spiral nebulae which are galaxies millions of light-years away. To understand the sun, it was necessary to learn the chemical make-up of stars. The first step in the exploration of intergalactic space was taken by philosopher Immanuel Kant and mathematician Johann Lambert and later by astronomer William Herschel.

Kant first became interested after reading a review of philosopher Thomas Wright's book, "An Original Theory or New Hypothesis of the Universe," which was most concerned with the location of God within the universe. The review distorted Wright's theories but led Kant to ultimately provide a glimpse of the universe of galaxies. Wright described the Milky Way as a flattened disc of stars and compared the grouping to a planetary system. It was Kant's contention that there was a universe of galaxies.

Kant summarized his findings and theories in a book that had only limited exposure. The subject of a universe of galaxies emerged again when Johann Lambert was appointed to the Berlin Academy of Sciences. Lambert wrote in his "Cosmological Letters" that the sun was a star on the a disc-shaped system of stars known as the Milky Way and that there were innumerable numbers of "Milky Ways."

William Herschel was the first astronomer to make "acute, systematic observations of the universe beyond the solar system" (p. 150). Herschel, a former musician, first became interested in nebulae when he read books by stargazers James Ferguson and Robert Smith who made references to fuzzy illuminated objects in the skies. Smith intimated that the larger the telescope, the more individual stars could be seen in these objects. Advancements were made in telescopes including those by Herschel who worked endlessly to develop a powerful telescope. Herschel stayed at his telescope observing the skies during most of his day. Herschel discovered the planet Uranus in 1781.

This discovery won Herschel a fellowship with the Royal Society and appointment as astronomer to King George III. He received a royal grant and was then given the honor of operating the world's largest telescope which was funded by the King's money. With this new telescope, Herschel discovered the sixth and seventh moons of Saturn. There were problems with such a large telescope and Herschel eventually returned to smaller telescopes. He was still intrigued with nebulae and accurately characterized the Orion Nebula as a hundred light-years from earth. He concluded that the Andromeda nebula was a cluster if millions of stars. Herschel's most important contribution was his pioneering efforts in leading astronomy into deep space.

# Chapters 9 and 10

## Chapters 9 and 10 Summary and Analysis

In Chapter 9, the author discusses how there were two schools of thought about elliptical nebulae. One was the theory of the "island universe" of Kant and Lambert. The other theory was the "nebular hypothesis" which theorized that the spiral and elliptical nebulae were clouds of gas that were forming new stars. As it turned out, both were correct. It was astronomer William Parsons who discovered that some nebulae had spiral structures. The photographs taken by Isaac Roberts in England in the 1880s proved that most were spirals. James Keeler estimated that the existence of over one hundred thousand such spiral nebulae was possible.

A combination of the telescope, the camera and the spectroscope would ultimately reveal the composition of the stars. Joseph Fraunhofer elevated spectroscopy to an exact science. A spectroscope, fitted with a prism, broke up the light of a celestial object into a rainbow of colors. The spectral absorption and emission lines that were produced held the key to the chemical elements of the object that produced the light. In subsequent years, the spectroscope was able to detect the presence of barium and strontium initially and later sodium, calcium, magnesium, iron and other chemicals. With these discoveries, the new sciences of spectroscopy and astrophysics were born.

Scientists were able to confirm that the same elements found in the sun were also present in the stars. Unfortunately, the first nebulae that was scrutinized was of the gaseous variety and the erroneous conclusion was made that all nebulae were gaseous and none were comprised of stars. The sun was thought to be at the center of the Milky Way which, it was theorized, represented the entire universe—other than possibly dark enter space beyond it. However, at the turn of the century, the evidence of supernovae explosions captured on photographs indicated that these objects were exploding stars that were not in the Milky Way. A spectrum analysis of the Andromeda nebula proved that it was not gaseous but contained stars. The stage was set for the discovery of galaxies.

Harlow Shapley who worked under George Hale, director of the Mount Wilson Observatory, discovered variable stars, called Cepheid variables, and discovered the exact location of the sun within the Milky Way galaxy. Astronomer Henrietta Leavitt discovered the period-luminosity phenomena that enabled the distances of the Milky Way and objects in deep space to be measured. Shapley discovered globular star clusters that contained literally millions of stars. Through errors and miscalculations, Shapley over-estimated the size of the Milky Way and advocated the "big" galaxy theory. It was disputed by Hebert Curtis who was an advocate of the "island universe" theory.

It was in 1924 that Edwin Hubble began to take scores of photographs of the Andromeda spiral and deduced that Andromeda was located beyond Shapley's "big galaxy." Hubble's work began to poke holes in the nebular hypothesis and to favor the island universe theory. Through the 1930s and 1940s, Hubble and his assistant Milton Humason, charted and cataloged ever more distant galaxies. Advancements in measurements and corrections to faulty calculations began to provide the distance to far away galaxies and given the time it took for light to travel, astronomers realized that the galaxies and stars they observed had already died eons before.

In Chapter 10, Einstein's theory of relativity allowed physics to contend with the vast size of the universe and the higher velocities existing there. Newton was focused on the stars and planets—Einstein on the entire cosmos. Relativity portrayed space as curved and derived from that basis the phenomena that Newton attributed to gravity. Newton theorized that space was comprised of an invisible element he called aether that allowed the unimpeded movement of the stars and planets.

Olaus Romer detected periodic variations in time when Io, one of Jupiter's moons, went into eclipse. He was able to accurately detect the speed of light at 186,272 mph. Some scientists theorized that there could be an "aether drift," that the space that was thought to be stationary between objects actually had its own velocity. Physicist Albert Michelson and chemist Edward Morley conducted experiments which disproved any notion that the aether was in motion. Many scientists were not prepared to abandon the aether drift hypothesis and decided the Michelson-Morley experiment had been faulty. Physicists such as Hendrik Loretnz and Henri Poincare began to to edge toward a theory of relativity, Poincare concluding that no object could travel faster than the speed of light.

Young Albert Einstein had always been a rebel and graduated from Federal Polytechnic Institute in Zurich in 1900 with unexceptional marks. He couldn't get a job as a scientist or science teacher so he became a math and physics tutor. In 1905, Einstein began to focus on physics. In that year he wrote four important papers that served to transform science. These four papers laid down the foundation of quantum physics; altered atomic theory, changed statistical mechanics; and, presented the theory of special relativity. Newton had been replaced by Einstein as the the preeminent physicist of all time.

Einstein was influenced by physicists and scientists who preceded him. In addition to Newton's theories, he studied the work of James Maxwell and Michael Faraday on their theories on the electromagnetic field. The eventual emergence of Einstein's theory of relativity was not accompanied by celebration and acclaim. His first presentation was held at a Carpenter's Union Hall, not at a university. His work received no certification from leading scientists of the day. The claims that a person traveling in space would not age at the same rate as his counterpart on earth and that atomic clocks on a spaceship would slow down were met with derision.

Einstein's theory and its implications were considered strange at best. Poincare had coined the term, "theory of relativity," but the conservative Einstein preferred to call his hypothesis the "invariance theory." None the less, the term "relativity" stuck and Einstein's work was all embracing—taking in the widest berth of study possible including light, space, time and matter. It was verified that electromagnetism was a powerful force and held together everything in the universe together—from a star to a piece of paper. Einstein proved that energy caused a decrease in the inertial matter of an object. This concept was captured in his formula E = mc2 which translated to Energy equals Mass times Velocity squared. This formula was later used by astrophysicists to determine the thermonuclear process that power the stars.

Einstein improved on Newton's theories on gravity. He reasoned that since the impact of gravity was similar to that of acceleration, gravity could be a form of acceleration. This concept led to his theory of a four-dimensional space-time continuum in which gravitation was acceleration. Einstein had been greatly influenced on this theory by his mathematics professor, Hermann Minkowski who said, in essence, that time and space were both essential for there to be reality. In order to take his theory of special relativity to general relativity, Einstein had to abandon Minkiowski's space-time continuum because its space was flat. If gravitation was a form of acceleration, it would be contained in a curved space. Einstein, therefore, had to consider non-euclidean geometry which would add a fourth dimension. Fourth dimensional geometry had already emerged with the work of other mathematicians but it was considered arcane and lacking credibility.

By his own words, Einstein had never before worked so hard but in November 1915, he completed the theory of general relativity. This theory solved a long-standing question about whether the universe was infinite. General relativity proved that the universe could be finite in that it could contain a finite number of stars within a finite space. At the same time, it could also be "unbounded" or infinite. A four-dimensional cosmos is finite, however; due to the warping of matter, the cosmos appears unbounded when observed in three dimensions. His theory gained credibility, when the rays from the stars of Hyades during a total solar eclipse shifted the exact amount that the theory calculated. The curvature of space was confirmed in subsequent experiments.

# Chapters 11 and 12

## Chapters 11 and 12 Summary and Analysis

In Chapter 11, Einstein's theory indicated that the universe was not static, that it was constantly expanding. There was no real evidence; however, but logic told Einstein that there was validity to the concept. He added what he termed the "cosmological constant" to his theory which, to him, disturbed the beauty of it. That addition was later debunked by Aleksandr Friedmann who discovered that the physics maestro had made a calculation error. American Vesto Slipher published a paper in 1917 which provided evidence that the universe was expanding. Slipher, trying to capture rotation velocities of nebulae, discovered a red shift, or Doppler shift, in the spectral lines of spiral galaxies. The red shift in a spectroscopy indicated movement away from, in theses cases, the earth.

Slipher didn't fully understand what he had discovered but his findings were later used by Edwin Hubble in 1929 who confirmed movement away from earth and evidence of cosmic expansion. Hubble was not versed on the theory of relativity and was reluctant to come to any solid conclusions. Hubble referred to it as "red-shift distance relation" but was reluctant to say what it really was—cosmic expansion. The man who associated the red-shift of the galaxies with Einstein's relativity was a Belgian priest and mathematician named Georges Lemaitre. In fact, he published a paper making this connection in 1927, two years before Hubble's work but no one paid attention to it.

Finally given credit for his work, Lemaitre began to wonder how the universe came into being. Perhaps there was just a single quantum of energy that erupted and unleashed the universe. Later, astrophysicist Fred Hoyle referred to that moment as the "big bang." Russian scientist George Gamow theorized that the beginning of the universe may have started with a core so hot and dense that it created nuclear fusion and created the elements now known to man. There were three basic areas of study relative to the expansion of the universe: 1) the red-shift of the galaxies; 2) cosmic background radiation; and, 3) the age of the universe.

In Chapter 12, all the great minds of antiquity including Plato, Aristotle and Pythagoras, agreed that it took many "great years" for the universe to form and that it was completed when the planets were created. Aristotle concluded that the process was part of an infinite repeating cycle of development and destruction. This theory even suggested the possibility of immortality. If Aristotle was correct, there would be no way to determine the age of the universe. In order to gauge the age of the universe, its lifetime had to be thought of in linear terms. It was with the advent of Christianity that a linear time-line was estblished. Christianity supported a definitive beginning to the universe. Although not scientific, Biblical scholars estimated the age of the earth from the scriptures.

Geologists dug up and dated medallions, ancient inscriptions and other artifacts in an effort to determine the age of the planet. These scientists dug deep in the earth, with the held of the steam engine, and studied the stones of the ages. The geologists began to believe that the history of the earth might be contained in the strata that was being uncovered. They noted that the same fossils and elements were found in the same levels of strata. The fossils discovered were those of animals that no longer existed a factor that was in direct conflict with the Bible that told that all animals were created at the same time.

As more and more fossils were unearthed, the fundamentalists took comfort in the theory that a cataclysmic event had caused the destruction of species—like the Great Flood described in the Bible. Scholars and scientists saw it as evidence of a tumultuous and changing universe. Charles Lyell spent a lifetime studying the changing earth and rejected the concept of cataclysmic change; rather, he saw the earth in a constant state of flux. He argued that the same risks and dangers (a patch of black mold could be the source of the destruction of a rain forest) existed in all ages. From the data he gathered, it was theorized that the earth was millions of years old.

# Chapters 13 and 14

## Chapters 13 and 14 Summary and Analysis

In Chapter 13, Charles Darwin based his hypothesis that the world was old and always changing on the works of Lyell. During his five-year world-wide expedition on his brig, the Beagle, Darwin saw the richness of the world that few had ever seen. In Chile, he found marine fossils on mountaintops. In 1834, heading from the Galapagos Islands, he theorized that the Dangerous Archipelago was once a series of volcanoes.

As a young man, Darwin had been a creationist. Evolution was not a new concept to him. In fact, his grandfather Erasmus Darwin had written the book, "Zoonomia," an evolutionary work about the possibility that all life came from a single ancestor. Darwin's book, "The Origin of the Species," had three main premises: 1) that there were variations within species; 2) that living creatures create more off-spring than nature can support; and, 3) that survival is based on the process of natural selection. It was Darwin's theory that natural selection led to the origin of new species because nature favored those variances. The more diversified a species became, the more likely was its survival.

Although Darwin wrote his theory in a 230-page essay, he did not publish it for fifteen years. One explanation for this delay was that Darwin suffered from ill health. But the bigger possibility was that he feared the outrage that his ideas would provoke from the religious community. His concept that men and animals had the same origin would not rest well in many circles. He also knew that many in the scientific world would also have objections to his theories. Darwin had seen what happened to others who wrote books that even hinted at evolution. Besides, he didn't have evidence—genes were an unknown at the time.

Darwin finally published his theories in conjunction with another naturalist, Alfred Wallace, whose findings were very similar to Darwin's. The strength of Darwin's book, although very lengthy, was how it appealed to a basic logic in the reader. It was very persuasive to many scientists and scholars who soon came to adopt his theory. However, the reaction of the religious community had been exactly what he had feared. Darwin was ridiculed and excoriated. And, his theory was in direct conflict with with the Bible in many respects, including the estimated age of the earth.

Darwin had no way of proving the age of the earth. That would be for physicists to determine through the science of thermodynamics. Since the earth was still emitting heat from its core, its rate of cooling could determine its age. But the leading physicists were more concerned with the temperature of the sun. Physicist Hermann von Helmholtz was certain that the sun would have burned out eons before if it were just on fire. He reasoned that the material that the sun was comprised of settled back toward the sun and refueled itself which indicated that the sun could last for perhaps 40 million years—much longer than what was written in the Bible. Lord Kelvin theorized that the sun could not have been burning for more than 500 million years which was in conflict with Darwin's estimation. The men admitted that there was missing data from both of their hypotheses.

What both men were not aware of was the forces of nuclear energy which stemmed from the decay of radioactive material, the process that provided heat from the earth's core. It was learned much later that nuclear fusion powered the sun. Physicist Wilhelm Rontgen accidentally discovered X Rays in 1895. In 1896 in a similar situation, Henri Becquerel accidentally discovered radioactivity. It wasn't long until other scientists figured out that radiation could produce vast quantities of energy. In the process, the presence of radioactive materials attested to the age of the earth. Through Carbon-14 dating, it was possible to learn the age of every living thing.

In 1938, German chemists Otto Hahn and Fritz Strassman were the first to describe nuclear fission, a process which released energy by splitting nuclei. In 1939, American physicist Hans Bethe identified nuclear fusion which which released energy by combining nuclei. There had been concern about nuclear weaponry as far back as 1903. This concern became a reality when the first atomic bomb was tested in New Mexico in 1945 and when two A-bombs dropped on Japan ended World War II.

In Chapter 14, by the beginning of the twentieth century, it was obvious that atomic energy powered the sun and stars. To fully understand exactly what took place within these celestial bodies called for a coordinated effort between physicists and astronomers. The first important step was to determine the structure of the atom. Initially, only one of the three elements of the atom had been identified—the electron. Still to be discovered was the presence of the proton and neutron. Ernest Rutherford discovered that atoms of heavier elements had more protons and neutrons in the nucleus and additional electrons in their shells. The atom of simple hydrogen, a gaseous material, contained only one proton. The number of electrons in the nucleus determined the atom's electrical charge.

Despite advancements in the study of stars, no one had determined why stars glowed. Human "computers" at Harvard or mainly women who were barred from attending classes, were hired to review photographic plates that contained images of thousands of stars. In 1915, Annie Cannon determined that stars fell in six different spectral classes. They were arranged by color from blue-white to yellow (like the sun) to red. Scientists were later able to categorize stars by their absolute magnitude. An astrophysical "fossil" record was developed in order to determine the ages of stars. The glowing of a star was eventually attributed to "quantum tunneling" and the activity of the photon. Two fusion processes were identified in stars: the proton-proton chain reaction and the carbon cycle.

It was later theorized how stars die. When an ordinary star like the sun burns its fuel down, its core contracts and its outer portion expands and cools becoming a red giant. After the cooling process, it contracts and becomes a white dwarf. When a blue giant star exhausts its fuel, it becomes unstable and explodes in a supernovae. Scientists questioned how stars, which manufactured light elements like helium, also made heavy elements and whether stars were the sole source of all elements. Some held that the original source of elements was the big bang. Astrophysicist Fred Hoyle put forth a paper in 1954 that asserted that red giants could transform carbon into oxygen. In 1956, Astronomer Paul Merrill discovered the presence of technetium-99, an element heavier than iron, in the spectra of stars. Apparently, stars did create heavy elements even though physicists couldn't figure out how they did it.

Scientists worked on the question of the origin of elements for decades. Hoyle along with nuclear physicists Willy Fowler and Geoffrey Burbidge issued a paper in 1957 in which they demonstrated how a star's fusion process along with the proton-proton reaction and carbon cycle could build heavy elements. A neutron star is a dying star that spins rapidly and emits radioactive pulses. An exploding star generates enough power to create a variety of heavy atoms including those of gold, silver, mercury and iron. These elements are blown into clouds and are inherited by planets that orbit around newly created stars.

# Chapters 15 and 16

## Chapters 15 and 16 Summary and Analysis

In Chapter 15, quantum physics first emerged in 1900 when Max Planck theorized that energy came in discrete units called quanta. His theory led science into the subatomic world and was destined to destroy classical physics. One element of quantum physics was that one could either determine where a particle was or its trajectory in motion - but not both. This eliminated the ability to predict the path of a particle. This revelation marked a fundamental change in physics.

Examining the subatomic world more closely, physicists learned that when an electron was elevated into a higher orbit, it moved from lower to higher orbit without traversing the intervening space. This phenomenon was referred to as the quantum leap. The scientists learned that objects appeared totally different in the subatomic world than they did under normal observation. They also realized that the scientists' own presence in the observation of tiny particles altered them. Classical physics was deterministic—quantum physics could only deal in probabilities not certainties.

The "probability" nature of quantum physics bothered Einstein who thought a some point a quantum theory of certitudes would be developed. It was not all smooth sailing for quantum physicists. There were misconceptions, difficulties and obstacles. However, through all the turmoil and confusion, the field of quantum physics gained credibility and eventually was considered one the the greatest intellectual achievements of all time.

In the world of quantum physics, there are two categories of particles: particles with fractional spin called fermions and those of integer spin, called bosons. Simply put, fermions comprise matter and bosons convey force. There are four basic forces: gravitation; electromagnetism; strong nuclear forces; and, weak nuclear forces. Fermions fall into two categories: quarks which respond to force and leptons which do not react to force. There are six types of both quarks and leptons; however, they do not appear to have any internal structure and are the basic particles of matter. Although the behavior of gravitation still holds in Einstein's theory of relativity, there is a breakdown when it comes to gravitational fields within black holes. Physicists late in the twenty-first century were still attempting to find one theory that would unify all others.

In Chapter 16, the author describes theoretical physicists, saying,"Theoretical physicists, like artists are guided in their work by aesthetic as well as rational concerns" (p. 301). Aesthetics are, of course, subjective. Beauty in the eye of a scientist relies on symmetry or the repeating of a measurable quantity. Also important to symmetry is proportion. Symmetry is familiar to everyone. It exists in art and in music. Facial beauty is generally measured by its symmetry. It can be seen in nature in the nautilus shell.

Symmetry also exists in science. German mathematician Emmy Noether provided evidence that every conservation law is based on symmetry. Physicist Eugene Wigner touted the principle of invariance in the laws of nature which is represented by symmetry. Einstein employed the elements of symmetry in his theories and proved to be most powerful in the field of quantum physics. All protons are identical as are all neutrons and electrons. Larger symmetries may be uncovered that link photons and electrons.

Symmetry can be used to identify previously unknown particles and can lead to the discovery of unknown fields. The "gauge" field theory is the foremost method of such discovery and is considered, behind relativity and quantum physics, as the third greatest advance in theoretical physics. Yang and his colleague Robert Mills together created the gauge theory which stated that "symmetry is the overweening principle, and that force is but nature's way of expressing global symmetries in local situations" (p. 310). They also concluded that force exists for the maintenance of invariances.

Other scientists and physicists began conducting other experiments using the gauge field theory with varying results. Steven Weinberg, Sheldon Glashow and Abdus Salam developed a unified electroweak theory that found a relationship between the weak and electromagnetic forces. The three men came from diverse backgrounds and worked separately and jointly for years to prove their theory. Two major testing labs - CERN in Geneva and Fermilab near Chicago - engaged in heavy competition to test the electroweak theory in their accelerators. CERN was the most aggressive of the two labs and decided to create their own proton-antiproton collider. It took three years and millions of dollars to build the collider. Tests began in 1982 and the collider worked perfectly. Fermilab built their own apparatus which began operations in 1985. The US began planning the building of a superconducting super collider which would become the largest machine ever constructed. Weinberg, Glashow and Salam ultimately won the Nobel Prize in Physics in 1979 for their accomplishments.

Experimental physicists worked for years on trying unify theories and in attempting to isolate a decaying proton but had no success. Initially in the Soviet Union and then later in the west, super-symmetry theories were developed that linked bosons with fermions. But something was missing and that something was the "string" - a particles that is longer than it is wide. But using the string theory proved to be limited to just certain dimensions and was difficult to experiment with and test. Was there perfect symmetry to be found in the multidimensional universe? If perfect symmetry ever did exist in the universe it was at the very beginning. As the universe evolved, it began to lose its symmetry and trying to discover it is tantamount to looking for the beginning of the universe.

# Chapters 17 and 18

## Chapters 17 and 18 Summary and Analysis

In Chapter 17, the last part of the twentieth century will be known in the world of science as the era where the smallest particles that existed were studied in tandem with the vast universe. Among physicists and astronomers, there was an overlapping of interests. The emerging super-symmetry theories hinted that all four forces might be linked. The development of an axis of historical time into cosmology and particle physics had benefits for both categories of scientist. The fundamental particles provided answers to some mysteries of cosmology and cosmology provided a testing ground for particle physics theories.

There are similarities in the sciences. The accelerators, like the telescope, is a form of time machine. A telescope looks into the past in that the light it captures has traveled for light years from the source. An accelerator creates conditions that existed in the early universe. Looking in the past takes the observer on a journey from quarks to atomic nuclei to atoms and finally to galaxies of stars. During that journey into the creation of the universe, there may have been a short period during which the universe expanded more rapidly than before or after. This concept is referred to as the inflationary universe theory. The search for one unified theory continues and if one is ever developed, it will be able to describe the universe at less than 10 -43 second after the big bang.

There is suspicion that there may be undetected matter which astronomers refer to as "dark matter." Gravitational mass accounts for only a fraction of the visible matter. Something else is out there—perhaps subatomic particles left over from the big bang.

In Chapter 18, man has always speculated about the origin of the universe. Various cultures had different beliefs based on myths, creative minds and sometimes fear. Science and technology has destroyed old legends and have taken a stab at how the cosmos originated. There are two main hypotheses: The vacuum genesis argues that something came from nothing and the quantum genesis advocates the application of the random nature of "quantum flux" to the early universe.

The first physicist to conceptualize the vacuum genesis was Edward Tryon. It came to him one day that perhaps "the universe is a vacuum fluctuation." (353) Colleagues laughed and thought he was joking but it didn't deter him. He visualized the universe erupting from nothing and characterized it as a quantum fluctuation. The universe could have emerged from nothing without violating any natural laws since the energy emitted from celestial objects (positive) is balanced by gravitation (negative) resulting in a net zero amount of energy.

The universe is still expanding from the big bang but it is thought to be slowing due to the gravitational pull of the celestial objects created in its wake. The inflation hypothesis was first conceptualized by American physicist Alan Guth. Initially, he didn't know much about cosmology but soon was drawn to it and began to work on how magnetic monopoles may have been created in the early universe. Guth found a problem with the grand unified theories that had emerged at that time because they predicted the production of too many monopoles. In December 1979, Guth headed a piece of paper with the title, "Evolution of the Universe," and began to write down calculations supporting the theory that the universe had evolved much more rapidly in the past and had slowed down.

According to the inflationary theory, the radius of the universe increased by 1050 times during less than the first second of time after which the quantum stability caused the expansion to slow. Guth came to support the quantum vacuum. Further, if the universe started in a quantum flux in a vacuum, it stood to reason that other universes could have been born. It is conceivable that every time a supernova star explodes, a universe could be created on the other side of space time - on the far side of the black hole the explosion ultimately collapses into.

Quantum genesis provides some stranger theories but equally as possible as those of the quantum vacuum. Stephen Hawking, holder of Newton's Chair at Cambridge University, began to try to understand the origin of the universe in terms of quantum probabilities. Hawking made what he referred to as a proposal for a quantum state of the universe. The universe is still expanding but billions of years in the future the expansion will stop and the universe will collapse and become a ball of fire which will mark the end of time.

# Chapters 19 and 20

## Chapters 19 and 20 Summary and Analysis

In Chapter 19, the advancements in physics and astronomy has drawn man closer to the universe. Astronomy has destroyed the notion that man is sealed off from the rest of the great beyond. Quantum physics has demonstrated that man cannot be a detached observer. Astrophysics has shown that the same matter and elements exist everywhere. Darwinian evolution has obliterated the barrier between man and animal by proving that we all originate from the same source. Man is an undeniable part of the universe.

The question that has plagued everyone from ordinary man to astrophysicist is whether life as we know it exists somewhere else in the universe. Darwin proved that life originated from the elements that exist on the earth. Since the same elements exist everywhere in the universe, the possibility of life exists throughout the cosmos. Our relationship with the universe could only be enriched if we were to discover the existence of life similar to our own on another planet. Einstein and Newton would not have been able to make the giant strides they did if they had only one planet to study.

Extraterrestrial life is not a new or even modern concept. Metrodorus wrote in fourth century BC that "to consider the earth as the only populated world in infinite space is as absurd as to assert that in an entire field sown with millet only one grain will grow" (p. 369). Space travel has been a notion to some men for centuries. In 1638, Protestant clergyman John Wilkins spoke of man's settling on the moon. Descartes asserted that life more intelligent than our own existed in the universe.

In the latter part of the 20th century, man began to abandon rhetoric in favor of actual exploration. Spacecraft was sent from earth to Venus, Mars, Jupiter and Saturn. Americans landed on the moon. But man is limited, for the time being, to his own solar system. The time and distance between earth and the planetary systems of other stars does not allow for exploration into deep space. Although man cannot physically make such journeys for the time-being, we can search for intelligent life by monitoring the skies for radio transmissions that might be sent from alien worlds. The establishment of SETI - the search for extraterrestrial intelligence - was first proposed in 1959 by scientists Giuseppe Cocconi and Philip Morrison. Not surprisingly, there was intellectual, cultural and political resistance to SETI's work. Some scientists wondered that if there were highly intelligent beings out there why hadn't they come to us. Others thought life on earth was an anomaly and the odds of it occurring elsewhere were negligible. Some politicians thought it was a big waste of money.

Because man has intelligence, he will continue to explore the universe—both physically and remotely. Perhaps the collective intelligence of man is the universe's way of evolving a brain.

In Chapter 20, man has had a "coming of age" in relationship to the universe. He knows where he is and through scientific leaders has learned much about his planet and the galaxy and the space beyond it. However, the more we learn the more we realize how much we don't know. Physician Lew Thomas wrote, "The greatest of all the accomplishments of twentieth-century science has been the discovery of human ignorance." (383) Contrary to critics, scientists do not have preconceived notions that they set out to prove. They are eager to grasp the unknown and try to make sense of it. Respected scientists do not make quantum leaps—they are cynical even about their own conclusions and test and re-test them ad infinitum in hopes of discovering a flaw or a reason to abandon them. Science is a process not a destination. As it trudges forward, it leaves many old concepts and theories in its wake.

# Characters

## Albert Einstein

Albert Einstein did not talk until he was three-years old. He was always a kind of a rebellious youngster and made only ordinary marks in school. After graduating from college, he could not get a job as a scientist or as a science teacher. To make a living, he was forced to hire himself out as a science tutor.

Although he showed little interest in the field of physics prior to the time, at twenty-six he became completely engrossed it in. At that young age, Einstein developed four theories that were destined to change physics forever. In these his work, Einstein presented the fundamentals of quantum physics, changed both atomic theory and statistical mechanics and, his most monumental achievement, presented the theory of special relativity.

Einstein, who at the time was an unknown in the world of elite scientists, was forced to present his theories at a Carpenter's Union Hall—no academic or scientific venue was available to him. As word of his theories was disseminated, his theories were initially looked upon with derision and were thought to be bizarre and baseless. The ambition of Einstein's work had never been seen before. It encompassed light, space, time and matter. When scientists began to take Einstein's work seriously, they found that his special relativity formula, E=MC2, was flawless. The formula was ultimately used by astrophysicists to determine the thermonuclear process that took place on the stars.

By his own words, Einstein's biggest challenge was the development of his theory of general relativity. It answered the question of whether the universe was infinite. Einstein's work showed that the universe could be both infinite and finite—due to its natural and inherent warping and depending upon perspective.

## Isaac Newton

Isaac Newton made his mark on physics when he developed his theory on gravitation. It totally destroyed Aristotle's concept of a dual sky. Unlike many scientists, Newton was unusual in that during his entire career as a scientist, he was in search of God. He also had unusual interests in mysticism as he had a life-long interest in alchemy and magic. Perhaps he was the best kind of scientist—one who was open to God, magic and science. He would believe whatever could be proven to him and left no stone unturned.

Just as many young geniuses, Newton was a lonely figure in college. He was apparently not interested in the good times that could be had on campus with his fellow students. He preferred to spend his time alone in his room reading the works of Plato, Copernicus and Descartes. Even though Descartes was a noted philosopher, Newton was intrigued by his theories on inertia and the solar system. When Newton developed his gravitational theory, he laid the groundwork to prove that the heliocentric theory of the solar system put forth by Copernicus centuries before was accurate.

After college, Newton focused on the gravity of the moon and planets that kept them in place. He initially accepted a position as a Lucasian Professor of Mathematics. As he became interested in the stars and planets, he decided he needed a more powerful telescope than was currently available. Not waiting for someone else to invent a better telescope, he invented a powerful telescope that was equipped with mirrors to collect light rather than lenses. It became the world's most popular telescope.

Newton developed three monumental laws of physics during his career. The first one expanded on the theory of inertia which stated that a body in rest tends to stay in rest. Newton added that a body in motion tends to stay in motion. Newton's second law proclaimed that force equals mass times acceleration ($F = ma$). Newton's third law proved that every action had a reaction. All of Newton's laws and his entire body of work changed dramatically the science of physics. And, until Einstein came along, he was considered the foremost physicist to have ever lived.

## Eudoxus

One of the earliest astronomers was Eudoxus. In 385 BC, he attended Plato's Academy in Athens. After Eudoxus' studies with Plato ended, he went on to establish his own observatory on the Nile and developed one of the first models of the universe.

## Aristarchus

Aristarchus was the first astronomer to suggest a heliocentric solar-system. He also estimated that there were much longer distances between the earth and the sun and moon than generally thought.

## Copernicus

Copernicus came to believe that the planets orbited the sun in perfect circles. Copernicus worked tirelessly for years trying to prove his theory. Most of his work was unpublished until hia death because he feared retribution from the church.

## Galileo

Galileo advocated Copernican astronomy. Galileo was more aggressive than Copernicus in his attempt to win approval for his work. The clerics thought he was offending God and the scholars feared that he would be proven to be brighter than they were. He was eventually arrested for his theories and spent the last years of his life in house arrest.

## Charles Darwin

Charles Darwin was a naturalist who worked his entire life on the origin on the species. After he completed his work, he delayed publishing it for fifteen years. Some attributed this delay to his ill-health but the real reason was thought to be his fear of retribution from religious sects.

## Max Planck

Quantum physics first emerged in 1900 when Max Planck theorized that energy came in discrete units called quanta. His theory led science into the subatomic world and was destined to destroy classical physics.

## Stephen Hawking

Stephen Hawking is a contemporary theoretical physicist who ascribes to the quantum genesis of the universe's origin. Hawking believes that the universe is still expanding but billions of years from now, it will stop expanding and will collapse in a ball of fire. The event will mark the end of time.

## Steven Weinberg, Sheldon Glashow and Abdus Salam

Steven Weinberg, Sheldon Glashow and Abdus Salam developed a unified electroweak theory that found a relationship between the weak and electromagnetic forces. The three men ultimately won the Nobel Prize in Physics in 1979 for their accomplishments.

# Objects/Places

## The Milky Way

The sun and earth's planetary system is located in a spiral galaxy named The Milky Way." The galaxy is estimated to have some 400 billion stars with more in the making.

## Spiral Galaxies

Spiral galaxies are large clusters of stars that are in the shape of an elongated oval and appear to be flat celestial objects. Spiral galaxies make up the majority of the galaxies that have been discovered thus far.

## Andromeda

Andromeda is the closest galaxy to the Milky Way Galaxy. It is a spiral galaxy and is approximately 2.5 million light years from earth.

## Heliocentric Planetary System

A heliocentric planetary system has its star at the center of the system with its planets orbiting around it. The earth's planetary system is heliocentric.

## The Origin of the Species

"The Origin of the Species" is the life-work of naturalist Charles Darwin. It contains his theory about the sources that created life. He provides evidence that all life came from the same source.

## Astrophysics

Astrophysics is the branch of astronomy that deals with the universe and the celestial objects located within it.

## Law of Inertia

Aristotle declared that a body in rest tended to stay at rest. Galileo completed that theory by adding that a body in motion tended to stay in motion, especially the denser their mass was.

# Einstein's Theory of Special Relativity

Einstein's Theory of Special Relativity is represented by the famous equation E = MC2. The formula indicates that energy is equal to mass times velocity squared. The equation was proven to be flawless and helped astrophysicists to study the thermonuclear process that takes place on the sun and stars.

# Quantum Physics

Quantum physics was introduced in 1900 when Max Planck theorized that energy came in discrete units called quanta. His theory led science into the subatomic world and was destined to destroy classical physics that existed prior to its emergence.

# The Quark and and the Lepton

Particles known as fermions fall into two categories: the quark, which responds to force and the lepton, which does not react to force. The quark and the lepton are the smallest particles in existence. They do not have an internal structure that can be broken down.

# Themes

## Man's Intelligence

Charles Darwin and other naturalists discovered evidence about the origin of man. In his work entitled, "Origin of the Species," he provided his thesis that man and all animals developed from the same single source - the same elements, particles and conditions created all life. But man stands out above all other animals. And what separates man from the rest of the living creatures on earth is his intelligence. Without that intelligence, who would know that man and animals were created from the same elements? Certainly not an elephant or a kangaroo!

Man's intelligence, especially that of the great physicists, astronomers, and other scientists, has revealed a great wealth of information about the earth we live in, the planetary system where our earth is located, the Milky Way galaxy in which our planetary system is located and then the great expanse of space that is beyond that. It was man's intelligence who continued to peer into space and try to make sense of what was out there and how it affected mankind.

Through literally centuries of work, tenacious astronomers learned that our star, the sun, orbited on an outer edge of a spiral galaxy called the Milky Way that contained some 400 billion stars and no doubt planetary systems orbiting around many of them. Astronomers and astrophysicists determined that the universe was literally an "island universe" that it was home to millions of galaxies like our own. They also uncovered that there were untold numbers of galaxies being created on a constant basis, with billions of new stars and planets being created within them.

As is often said, the more man learns the more he realizes he doesn't know. Why is there a universe? What existed before the universe came into being with the Big Bang? Is the universe infinite? Why was mankind created? One theory offered by the author is that perhaps the universe created man and his intelligence as its rather awkward way of attaining its own brain. Stranger things than that are probably occurring right this very minute. If anyone can figure out the cosmos and all its mysteries, the only being who can is man. Until another species shows up sometime in the future, it is all up to man to find the answers to these questions that have lingered over all time.

## Man's Relationship with the Cosmos

Even early man had a curiosity and attraction to the skies and stars above. There was an explicable connection that has always existed. Although the skies and stars were distant and mysterious in days of antiquity, man's experience with the universe has been a positive one. The simple explanation for that feeling of benevolence is that man instinctively has always instinctively felt he was part of the cosmos. The Pharaohs of

Egypt wanted to feel "at one with" the universe as witnessed by their alignment of the Great Pyramid of Giza with a star. Stonehenge's design was based on the stars.

Early man went to great lengths to feel a part of the great skies above him. The ancient Sumerian, Chinese, and Korean astronomers would climb to high elevations to try to see the stars more clearly. While ancient cultures didn't understand the depth of space, there was an internal need that compelled man to try to be closer to the cosmos. And why not, the stars were their friends. They helped man keep time and guide him through land and sea. Early farmers used the sky as a calendar that told them when to plant and harvest. American Indians lost in the woods relied on Father Skies to guide them home. Indian tribes looked to the skies to mark the days of the lunar month.

When mysteries about the universe were unlocked here on earth by naturalists like Charles Darwin and Alfred Wallace, man's link to the universe became more apparent. The very elements that existed on earth and that were the building blocks of life were found, by astrophysicists, to exist everywhere. The elements found on earth and that made life possible came from exploding stars. Supernova explosions disbursed its elements into space where they were captured in gaseous clouds that through aeons formed the Milky Way Galaxy and the sun, earth, and man.

As advancements were made in quantum physics, the connection to man was made ever more evident. In this subatomic world the quarks and leptons that exist within each quanta appear to have no internal structure and are the basic particles of matter - the basic particles of us all.

## Origin of the Universe

Although scientists, astronomers and physicists ostensibly study the nature of space, stars, planets, and galaxies, there is an underlying burning question that is always in the back of their minds. How did all this begin and why? What is the true origin of the universe? The Big Bang Theory is accepted in most scientific circles but there is a question behind that concept. What particles existed that created the circumstances that made the Big Bang possible? And, how did those first particles and elements form?

Down through the ages, it has been religion that has answered that question for many. The Bible tells us that God created the world and the earth and sun as well as man. That has been enough for many Christians. Other religions and cultures provide similar answers to the mystery of life and the universe. And the answer to the "why" part of the question has be accepted by many that man was created because God loved man. But does that in any way answer the question as to why there are billions of stars and vast and even infinite space?

It has been scientists who have at least attempted to offer solutions for at least part of this question. The "why" part of the issue has not been addressed by astrophysicists since there are no laws of physics that could address it. There are two hypotheses about the origin of the universe. One is known as the "vacuum genesis" and states that the universe was created from nothing. The "quantum genesis" declares that the answer lies in the random nature of "quantum flux." While neither explanation is satisfying to the average person, the scientists who developed these hypotheses based them on physics. But these concepts are merely a starting point and physicists and astronomers of the future will continue to seek definitive evidence as to how the universe began. Perhaps once that part of the myster is solved, they will address why it all began.

# Style

## Perspective

"Coming of the Age in the Milky Way" by Timothy Ferris is the history of astronomy from the early stargazers who were inexplicably drawn to the stars through the major advancements made by astrophysicists and other scientists who ventured into untouched territory from Newton's law of gravity and to Einstein's theory of general relativity and into the subatomic world of quantum physics.

The book is narrated by its author and is told generally in the third person, although there are some flashes of first-person narrative interspersed throughout the book. There probably could be no better source to write this book. Ferris is considered the best popular-science writer in modern times according to the Christian Science Monitor. The Washington Post referred to Ferris as "the best science writer of his generation." His background in journalism helped him to maintain a reporter's unbiased approach to the subject matter.

Ferris is an accomplished author having written the bestselling "Seeing in the Dark," "The Whole Shebang," and "The Red Limit," among other books. The author teaches the reader about the history of astronomy and astrophysics which is accomplished very successfully due to his background as a emeritus professor of journalism at the University of California at Berkeley.

## Tone

Not surprisingly, the tone of the book, "Coming of Age in the Milky Way" by Timothy Ferris, is written in a teaching, professorial tone. Ferris is an emeritus professor of journalism at the University of California at Berkeley where he teaches his students to present all sides of an issue and to write only the facts and write them with clarity. He has followed his own ad vice in the writing of this book. And on the subject of science, Ferris is considered to be on of the best science writers on the modern scene.

The book is about the science that has led man to become closer to the universe of which he is an undeniable part. From the beginning of the book which describes how ancient man related to the skies and stars all the way through the conclusion which focuses on the subatomic world of quantum physics, the narrative is written in a clear as manner as possible, considering the complexity of the material and subject matter. The narrative is rich with details, historic facts and anecdotes that make the work a compelling read and a page-turner despite subjects that are foreign to the ordinary person.

It is obvious that Ferris went to great lengths to write a history of astronomy and mankind's "coming of age" in the cosmos and that his research was extensive and all-encompassing. It is also apparent that Ferris has a great deal of admiration and respect for the advancements made by scientists through the ages and has an even greater respect for the cosmos which, for every question man answers, only presents double the number of questions.

## Structure

"Coming of Age in the Milky Way" by Timothy Ferris is separated into three main sections. Part One: Space is separated into eleven chapters and describes the early development of astronomy through classical physics. Part Two: Time has three chapters and deals with the age of the universe and the evolution of atoms and stars. Part Three: Creation covers quantum physics and the origin of the universe.

Part one tells of man's early curiosity and theories about the skies and the stars. It tells of their simplistic views that the earth was superior to our bright star. In the second section, Ferris describes how man sought to find the answers to the mysteries of the universe here on earth. The third section delves into quantum physics where further evidence is provided that man is undeniably tied to the universe and to the subatomic world.

Following the main narrative, is a voluminous "Glossary." There is a section entitled, "A Brief History of the Universe," which provides a time-line of noteworthy events that occurred on the earth and in the universe. The book concludes with a "Notes" section; a "Bibliography" section; and an "Index."

# Quotes

"Had we never seen the stars, and the sun, and the heaven, none of the words which we have spoken about the universe would ever have been uttered. But now the sight of day and night, and the months and the revolutions of the years, have created number, and have given us a conception of time, and the power of inquiring about the nature of the universe; and from this source we have derived philosophy, than which no greater good ever was or will be given by the gods to moral man" (Chapter 1, p. 19).

"There will come a time in the later years when Ocean shall loosen the bonds by which we have been confined, when an immense land shall be revealed...and Thule will no longer be the most report of countries" (Chapter 3, p. 47).

"Amazed, and as if astonished and stupefied, I stood still, gazing for a certain length of time with my eyes fixed intently upon it...When I had satisfied myself that no star of that kind had ever shone forth before, I was led into such perplexity by the unbelievability of the thing that I began to doubt the faith of my own eyes." (Chapter 4, p. 61).

"Galileo on his knees before the Inquisition symbolizes the conflict between science and religion" (Chapter 5, p. 84).

"This universe that I have extended a thousand times. . . has now shrunk to the narrow confines of my own body" (Chapter 5, p. 101).

"Newton's surviving drafts of the Principia support Thomas Edison's dictum that genius is one percent inspiration and ninety-none percent perspiration" (Chapter 6, p. 116).

"The nebulae are systems of many stars lying at immense distances. Here for the first time was a portrait of the universe as consisting of galaxies adrift in the vastness of cosmological space." (Chapter 8, p. 148).

"I want to know how God created this world. I am not interested in this or that phenomenon, in the spectrum of this or that element. I want to know His thoughts, the rest are details" (Chapter 10, p. 177).

"Nowhere in human history is there to be found a more sustained and heroic labor of the intellect than in Einstein's trek toward general relativity, nor one that has produced a greater reward" (Chapter 10, p. 200).

"There is a grandeur in this view of life, with its several powers, having originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved" (Chapter 13, p. 239).

"President Truman in his final State of the Union message declared that 'the war of the future would be one in which Man could extinguish millions of lives at one blow, wipe out the cultural achievements of the past, and destroy the very structure of civilization'" (Chapter 13, p. 253).

"What really interests me is whether God had any choice in the creation of the world" (Chapter 15, p. 281).

# Topics for Discussion

Discuss man's early fascination with the universe? What were some early concepts of the greatest minds of the day including Aristotle and Plato?

What contributions to astronomy were made by Copernicus and Galileo? What risks did these men take in advancing their theories?

What theories did Albert Einstein develop at the age of twenty-six? Describe them. How did his theories impact physics?

How did Christianity impact the study of the universe? Discuss the relationship of religion and science.

Name the three greatest achievements in theoretical physics. Provide a brief description of each.

What is quantum physics? Why is it important to mankind and to the the study of the universe?

What are the two hypotheses that theoretical physicists have developed about the origin of the universe? Describe each theory. Which hypothesis does Stephen Hawking ascribe to and what future does Hawking see for the universe?