Johannes Kepler
(1571-1630)

By

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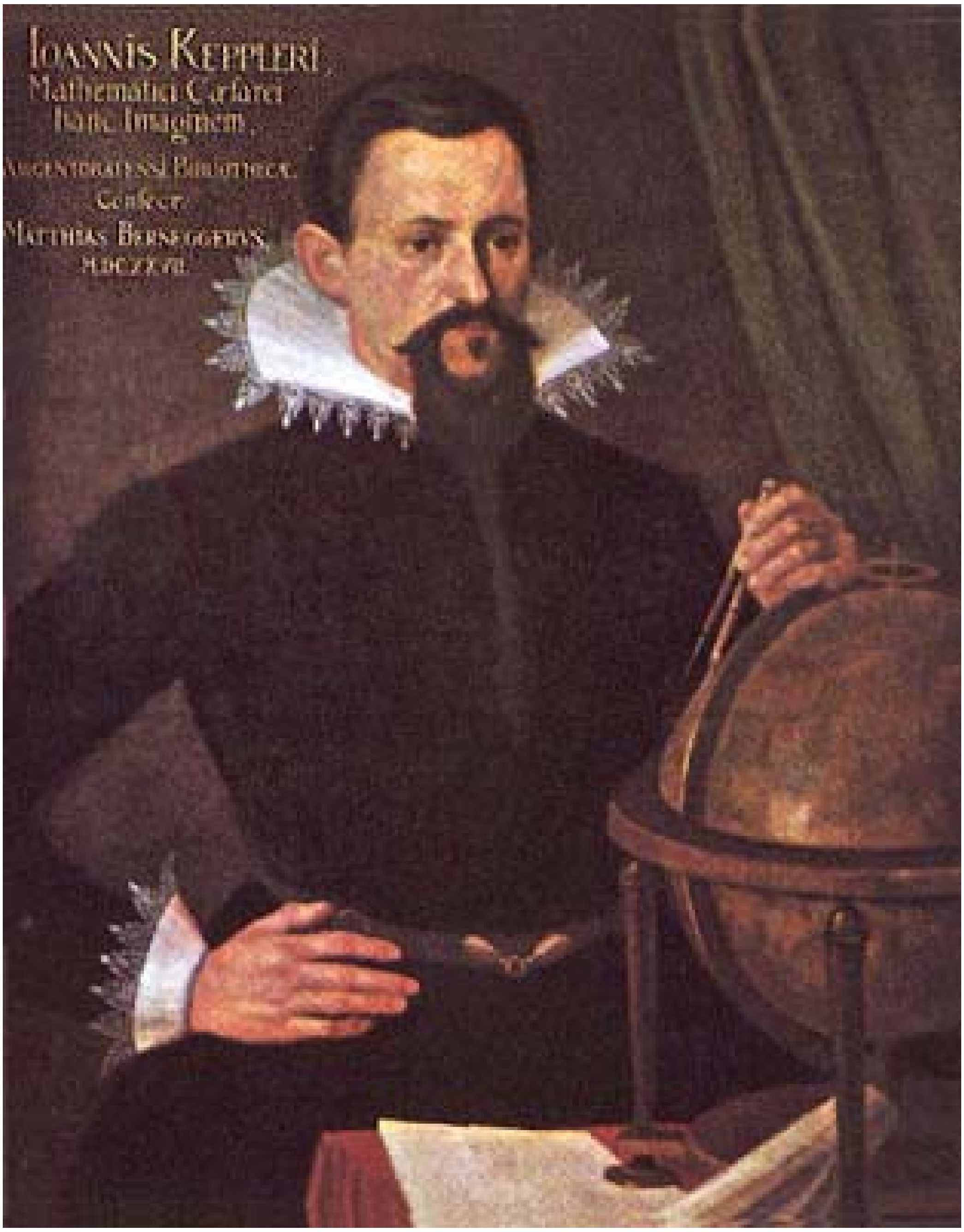


(E. Lessing/Art Resource, NY)

Johannes Kepler lived between the death of Nicholas Copernicus in 1543 and the birth of Isaac Newton in 1642. His life formed a critical bridge between these two great men. Kepler used the Copernican Heliocentric model of the universe to turn astrology into the modern science of astronomy. This fundamental base for science was used by Newton to develop the classical physics still used today to send men to the Moon, something Kepler himself discussed in his book entitled *Somnium*, published in 1634. Kepler validated the aesthetically beautiful ideas of Copernicus and paved the way for Newton's theory of gravity.

During Kepler's life William Shakespeare, Frances Bacon, Guy Fawkes and Milton were writing, Rembrandt was painting, Tycho Brahe was making precision observations of stars and planets, Galileo was using the first astronomical telescope, Elizabeth I was Queen of England, the Spanish Armada was sunk, the Mayflower sailed to North America, and the Inquisition was occurring in Europe.[1] Many of these people and events influenced Kepler's life and shaped the modern science of astronomy.

Johannes Kepler was born prematurely on 27 December 1571 at Weil der Stadt in Wurttemberg, Germany after a pregnancy that lasted 244 days, 9 hours and 53 minutes. His father was a mercenary soldier who was frequently gone from home. Johannes's mother, Katharine, was considered to be a nosey woman, and she had a vicious tongue. In addition she dabbled in occult types of activities. These personality traits were to later cause her and Johannes lots of personal difficulty with the courts. Johannes was the oldest of their six children. At the age of one year he contracted smallpox and thereafter was a sickly child. During his childhood his mother took him outside to view the great comet of 1577. She was interested in this apparition because it was believed that comets foretold dark events to come. Tycho Brahe observed this same comet form his observatory on the island of Hven. He concluded that it was farther away from the Earth than the Moon was. Michael Mastlin, at the University of Tubingen

[1] Michael Seeds, *Horizons Exploring the Universe* (Belmont, California, Wadsworth Publishing Company, 1995), p 75. In Figure 4-22, Seeds shows a timeline of the events and prominent people between 1500-1700.

also observed this comet. Both of these men would later have a great influence on Kepler's life. In that same year Kepler's father allowed him to view a lunar eclipse. The young Johannes had a difficult and interesting childhood.

Kepler wanted to be a Lutheran minister and attended schools for this purpose. As a boy he went to the Duke of Wurttemberg's School for Theology. Because of his sickly nature it took him twice as long to learn Latin as the other students. He was only a slightly better student when he arrived at the higher-level school in Maulbronn.[2] During his two years a Maulbronn he had no friends and became isolated and withdrawn. He believed that he was unworthy in the eyes of God and that he might never obtain salvation. However, he still aspired to be a Lutheran pastor of a church.

In spite of his perceived unworthiness, Kepler believed that God was the creator of the Cosmos. At Maulbronn he studied Greek, Latin, music and geometry. It was in geometry that he thought he saw God. He later wrote: " Geometry existed before the creation. It is co-eternal with the mind of God… Geometry provided God with a model for the Creation… Geometry is God Himself." Carl Sagan says, "… he (Kepler) dared to contemplate the Mind of God."[3] Kepler's obsession with geometry and reading the Mind of God became the driving force in his life.

At the age of 17 he enrolled at the University of Tubingen. It was here that his intellectual abilities were finally recognized and where he met Michael Mastlin, who was to become his teacher and lifelong friend. Mastlin taught Kepler about the new Copernican theory of the universe. However, at this time the Lutheran church still considered the geocentric universe of Ptolemy to be correct. Therefore, Mastlin could not publicly teach Copernican astronomy in his classes. Kepler saw a metaphor for God in the Copernican model. He viewed the Sun as God around which all the planets revolve and the universe is centered. So to him the heliocentric

[2] Carola Baumgardt, *Johannes Kepler: Life and Letters* (London: Gollancz , 1952).
[3] Carl Sagan, *Cosmos* (New York, NY: Random House, 1980), p56.

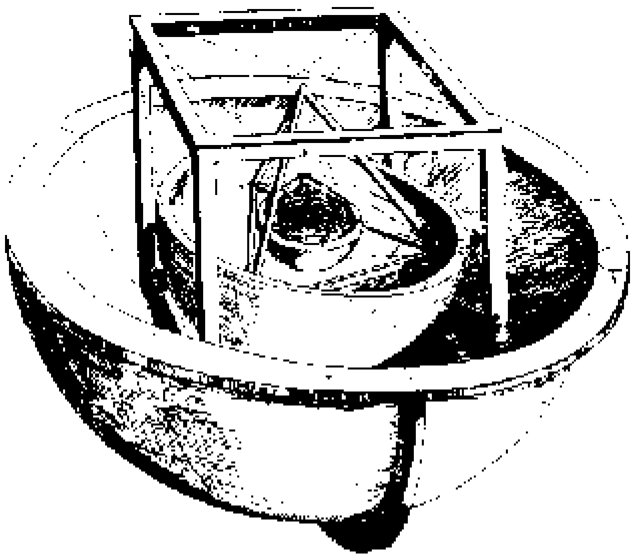
system was theologically correct and he saw no theological problem with adopting it as some church leaders believed.

Throughout his days at Tubingen he was unpopular and aloof. Many of his teachers thought he was unsuitable to be a Lutheran pastor. In 1594 the Protestant seminary for boys in Graz, Austria asks Tubingen University to supply them with a mathematics and astronomy teacher. Much to Kepler's disappointment he was assigned to this post. Kepler was not a very good teacher. He had only a few students his first year. When he taught class he mumbled, digressed off the subject matter, and was simply difficult to understand. By his second year he had no students at all. Kepler was as unpopular as a teacher as he had been as a student.

While at Graz, he continued his studies in astronomy and geometry. In addition he dabbled in astrology to supplement his poor salary as a teacher. It was during this time that he began his lifelong search for how the Universe was designed. He believed in the Copernican system that placed the Sun at the center of the Universe. Because the stars had no measurable parallax he believed them to be very far away, but there is no evidence that he thought they might be suns in their own right. In fact, that would have destroyed his notion that the universe was a metaphor of God himself. Ptolemy had described planetary orbits as perfect circles with the Earth being slightly off center. Kepler believed that the orbits were perfect circles because God would use a perfect geometric shape to construct the universe. The Earth had to be off center to account for the variable speeds observed for each planet as it revolved. So Kepler conceived the universe to be heliocentric with the planets orbiting the Sun along perfectly circular orbits with the Sun being slightly off center. At this time his idea for the Cosmos was a combination of the old Ptolemaic system and the new Copernican system.

In the Ptolemaic scheme, each planet had its own orbit around the Earth. Each planet had its own individual orbit with its own size. It had been suggested that each planet occupied its own separate layer in the sky. These layers were within spheres above the Earth with each sphere touching its neighboring planet's sphere. The Copernican model predicted a relative spacing between the planets and so the spheres could no longer touch each other. The problem now became that without spheres to hold them in place how could the planets stay in their regular orbits? Kepler, the mathematician, liked the idea of celestial spheres, and he also believed that Copernicus had developed the most correct model of the Cosmos. So Kepler wanted to merge the older celestial spheres idea with the planetary spacing predicted by Copernicus. Another question that was bothering Kepler was, why were there only 6 planets? These two questions led him to a three dimensional geometric solution which could simultaneously answer both questions.

One day while teaching at Graz, Kepler had a revelation that answered both the celestial spheres problem and why there were only six planets. He realized that there were only five regular solids that had equal sized faces. By fitting them into the spaces between the planets Mercury, Venus, Earth, Mars, Jupiter and Saturn he could produce the spacing predicted by Copernicus and still maintain celestial spheres. Therefore, the planets were held in their obits by nesting these spheres as shown in the figure below. In addition he had solved the reason why



there were six planets. There were only five solids and so this geometric framework could only support six planets. Kepler believed that he had finally understood how God had used geometry to construct the Cosmos. He presented this theory in his book *Mysterium Cosmograpium*[4] (*The*

[4] Johannes Kepler, Mysterium Cosmographicum, ed. A. M. Duncan (New York, NY: Abaris Books, 1981).

Cosmic Mystery) published in 1596 by the press of Michael Mastlin at Tubingen, his old university teacher. Kepler's universe, as presented in *Mysterium*, was very Platonic in nature. He believed that God had shown him the Truth of how the universe was constructed. It is thought that Kepler believed in the reality of regular solids holding up real spheres that contained the planets and stars. Owen Gingerich[5] claims that *Mysterium Cosmograpium* established Kepler as the first scientist to demand physical explanations for celestial phenomena. This is a departure from Platonic philosophy because Kepler believed that the Truth could be found by pure thought based on data obtained from observations or experiments. He believed that God himself was reviled by such observations.

A copy of *Mysterium* was sent to Tycho Brahe and Galileo Galilei. Galileo wrote him back and said he looked forward to reading the book and that he was also a supporter of Copernicus. Tycho sent him an encouraging reply, but did not believe in the reality of the spheres and their supporting structures as Kepler did. However, Tycho recognized the genius of Kepler's mathematical skills. The future interactions between Kepler and Tycho greatly influenced Kepler's life and modern astronomy.

There are two ideas of importance that Kepler discusses in the *Mysterium*. According to the Aristotelian physics of the time an object in motion would stop unless a force was applied to it to keep it moving. Kepler speculated that the Sun was producing some type of force that pushed the planets along in their orbit. Because Mercury was closest planet to the Sun and moved the fastest, and Saturn was farthest from the Sun and moved the slowest, he reasoned that the pushing force became weaker as the distance from the sun increased. In this idea he discusses an unknown force coming from the Sun. It was not until Isaac Newton invented gravity that this force was identified, but Kepler was the first to recognize that the Sun was responsible for the orbital motion of the planets. Kepler's second idea was more theological than scientific. He reasoned that the planets were created in perfect alignment like beads on a string. Therefore they

[5] Owen Gingrich, *The Great Copernicus Chase and Other Adventures in Astronomical History* (Cambridge, MA: Sky Publishing Corporation, 1992), p. 124.

all stated orbiting the Sun at the same moment. He thought that the Cosmos might end at some undetermined time in the future when the planets were again perfectly lined up as they were at the moment of creation.[6] There is no evidence that he attempted to calculate when this might occur.

After publishing *Mysterium* he married a woman of nobility, Barbara Muller von Muhlegg, on 9 February 1597. In order to marry her, Kepler had to prove he was of noble descent. This took him on a trip throughout Europe to obtain the appropriate documents. Kepler was willing to do this in spite of the fact that Barbara was only 22 years old and had already been married three times.[7] Their marriage was not the happiest of relationships, but the union lasted until Barbara died.

In 1598, Archduke Ferdinand persecuted any Protestants living in Graz. He ordered all Lutheran teachers to leave the city or be executed the next day. Kepler left and attempted to obtain a position at Tubingen University through his friend Michael Mastlin. Unfortunately for Kepler, but fortunately for modern astronomy, there simply were no jobs available at the university. However, Tycho Brahe was impressed enough with Kpeler's *Mysterium Cosmograpium* that he offered Kepler a job. On his way to join Tycho in Prague, Kepler returns to Graz to take care of some unfinished work. He was again forced to flee and went to Prague where he joined Tycho's staff in 1600.

Tycho's observatory, Uraniborg, on the Danish island of Hven had been the best astronomical observatory ever built up to that time. At this observatory Tycho had built the largest quadrants in the world. With these instruments he could observe stellar positions to a precision of one arc minute. During the years spent at Uraniborg he observed a comet and a supernova (of course Tycho did not know it was a supernova.) All of his observations convinced Tycho that the Aristotelian view of the universe was probably wrong. In 1597, the year before Kepler was force out of Graz, Tycho fell out of favor with the Danish nobility and was forced to close Uraniborg.

[6] Patrick Moore, *The Great Astronomical Revolution 1543-1687 and the Space Age Epilogue*, (West Sussex, England: Albion Publishing Limited, 1994.), p. 114.
[7] Corola Baumgardt, *Johannes Kepler: Life and Letters* (New York, NY: Philosophical Library, 1951), p. 29.

Tycho accepted a job as the Imperial Mathematician of the Holy Roman Empire in the city of Prague, which is close to Graz where Kepler was working.

Modern astronomy greatly benefited by both of these men being forced to leave their positions and meet up with each other in Prague. Kepler wanted to use Tycho's precise planetary position measurements to prove his model of the regular solids correct. Unfortunately Tycho had developed his own model of the universe and wanted Kepler to prove his model correct. Kepler did not believe that Tycho's model was correct, and was not willing to work on it. This made Tycho reluctant to hand over a lifetime worth of data to a young competitor. Because of this professional competition and their totally different life styles, modern astronomy was delicately balanced on the brink of their mutual distrust.

Kepler did not have to endure Tycho's flamboyant life style very long because Tycho unexpectedly died of his over consumption of food and drink about eighteen months after Kepler came to Prague. Tycho had attended a dinner party given by the Baron of Rosenbery. As was Tycho's habit he drank to much wine but refused to leave the table before the Baron. Because of his good manners Tycho developed a urinary track infection from which he died a few days later. On the night of his death he gave Kepler the observational data collected at Hven. To Kepler's dismay, Tycho's son-in-law claimed that all of Tycho's astronomical instruments and data belonged to the family and not to Kepler. Even after Tycho's death Kepler had to spend years in court dealing with Tycho's heirs.

Kepler used Tycho's observatory funding to gain access to the data. When Uraniborg Observatory was founded Tycho had been charged by Emperor Rudolph II to prepare new tables of planetary motion and to demonstrate the truth of Tycho's model of the universe. Because Kepler was the new Imperial Mathematician he had to be granted access to Tycho's data in order to fulfill the reason for funding the observatory in the first place. So, Kepler was allowed use Tycho's data even if he did not own it. The battle over ownership would continue for most of Kepler's life.

As Kepler used Tycho's data to develop a proper model of the Universe none of the accepted principles seemed to work. The only way to make these principles work was to assume that some of Tycho's observations had large errors. Kepler had great faith in Tycho's skill as an observer and was unwilling to admit to any such errors. Tycho had paid special attention to measuring Mars, so Kepler concentrated his efforts at making sense of the Martian measurements. As it turned out this was a good choice for reasons that will be discussed later.

While Kepler was busy working with the Mars data, an amateur astronomer, Johann Brunowski, saw a new bright star in the sky on the night of 10-11 October 1604. Kepler did not believe this extraordinary sighting of a new star until he saw it for himself on October 17th. By this time other astronomers, including Mastlin at Tubingen had also seen this new apparition. This star became one of the brightest stars in the sky and then slowly faded to invisibility. Kepler last recorded it in 1606. The appearance of such a star clearly indicated that the heavens were not constant and unchangeable. This star is now known as Kepler's supernova, and was the last recorded supernova until SN 1987a, which blazed into glory in February 1987. Because Kepler's supernova had no measurable parallax he concluded that it was very far away and in the sphere of the stars far beyond the planetary spheres.

Throughout the time this supernova was visible Kepler continued working on Tycho's observations of Mars trying to make logical sense out of them. In the older geocentric theories, the Earth had been placed at the center of the Universe, but not at the center of the planetary orbits. Instead it was positioned slightly off center of each of the orbits. Kepler had assumed that in the new heliocentric model the orbits would be perfect circles centered on the Sun. This seemed logical to him because it fit his idea that the heliocentric universe was a metaphor for God. In his mind God would have used a perfect geometric form, like a circle, so that the universe would be centered on him. Unfortunately, no matter how hard he tried, he simply could not make circular orbits fit Tycho's data. Recalling the old off center circles in Ptolemaic astronomy Kepler tried fitting an ellipse to the Mars data, and it fit almost exactly. Kepler was forced to conclude that the planetary orbits were ellipses and not circles. As it turns out the orbit of Mars is the most elliptical of all the known planets (except Pluto) and was an excellent choice. It was this unknown eccentricity that had caused Tycho to be curious about the motion of Mars.

Once the idea of elliptical planetary orbits was established in Kepler's mind he quickly developed his first two laws of planetary motion. They are:

> **Law 1:** A planet moves in an elliptical orbit, the Sun occupying one of the foci.
> **Law 2:** The radius vector, or an imaginary line joining the center of a planet to the center of the Sun, sweeps out equal areas in equal time intervals.

Both of these laws were written in his book *Astronomimia Nova* (New Astronomy) that was published in 1609. In *Astronomimia Nova*, Kepler speculated that the force emanating from the Sun, which pushed the planets along their orbits might be a magnetic force. This was the only natural force he knew about because gravity had not been invented yet. As it turns out magnetic force and gravitational force are both calculated using exactly the same mathematical form. Therefore, Kepler was very close to developing the idea of gravity, but this had to wait a few more years until Isaac Newton came up with the idea. At the time *Astronomimia Nova* was published it did not have the impact on the scientific community that it should have, because it was published as a limited edition and there were not many copies available.

Galileo Galilei was the first person to publish observations made with astronomical telescope in a book called the *Sidereal Messenger* that was published in 1610. Emperor Rudolph was very interested in astronomy and had made his own observations of the Moon with a simple telescope at about this same time as Galileo. The first copy of Galileo's *Sidereal Messenger* to reach Kepler was Emperor Rudolph's personal copy. Kepler's response to the observations published by Galileo was written in a short book entitled, *Conversation with Galileo's Sidereal Messenger*[8]. The use of this title and Kepler's references to Galileo being a messenger from the stars was later used against Galileo. This was unintentional because Kepler had published his work quickly without considering the consequences of his words.[9] Kepler did in fact believe the

[8] Johannes Kepler, *Conversation with Galileo's Sidereal Messenger*, ed. Edward Rosen (New York, NY: Johnson Reprint Corporation, 1965).
[9] Ibid. xiii-xix.

telescopic observations of Galileo and had built and used his own telescope shortly after writing this response.

Throughout this time in Prague political matters had been getting worse. Emperor Rudolph, who paid Kepler's salary, lost power and was replaced by Archduke Mathias in 1611. Also in that same year Kepler's son, Frederick, died and later that year his wife, Barbara, also died, so Kepler no longer wanted to stay in Prague. He accepted a post as District Mathematician in Linz, Austria. Even though Kepler made few friends in Linz he did remarry and Emperor Mathias attended the wedding.

Kepler's first few years at Linz were filled with a turbulent personal life. First his mother was accused of witchcraft. As she had gotten older she grew more disagreeable and nosey then ever before in her life. In 1615 she was brought before the local court. The judge threatened her with death unless she cast a spell to cure a woman that she allegedly had bewitched. Of course this very act would have incriminated her of actually being a witch. When she was finally released she fled to Linz to live with her son. After a short period of time she returned home and was promptly arrested and Johannes went to her aid. During the long three-year trial she was shown the instruments that could be used to torture her. However, she was not harmed and was eventually found not guilty. She died a year later. Secondly, his friend, Emperor Mathias, died and was replaced by Ferdinand, the same ruler that had forced Kepler to leave Graz back in 1598. Fortunately Ferdinand chose to leave Kepler alone for a few years.

In spite of these difficulties Kepler published two more books in 1619, which were entitled *Harmonice Mundi* (*Harmonies of the World*[10]) and *Epitome Astronomica Copernicae* (*Epitome of Copernican Astronomy*[11]). The first book was filled with a lot of scientific speculation. It is in this volume that he first states his 3rd Law of Planetary motion. Also in this volume, Kepler gave the orbital motion of each planet musical notes and attempted to write music based on the harmonies he thought might exist. The second book was more like an astronomy textbook than a

[10] Johannes Kepler, *Harmonies of the World*, ed. Charles Wallis, (Amherst, NY: Prometheus Books, 1995).
[11] Johannes Kepler, *Epitome of Copernican Astronomy*, ed. Charles Wallis, (Amherst, NY: Prometheus Books, 1995).

scientific presentation of new ideas or concepts. With all of his personal problems it is astonishing that he accomplished anything in his professional life during this period.

It was nearly ten years after publishing his first two laws that Kepler finally wrote his 3rd Law in *Harmonice Mundi*. Kepler's 3rd law can be stated as

> **Law 3:** The cubes of the mean distances of the planets from the Sun are proportional to the squares of their periods of revolution.

This last law makes it possible to construct a complete scale model of the Solar System. However, to do this at least one actual distance needs to be known. Kepler did not know any actual distances between the Sun and any planet. Therefore, he guessed that the Sun was 14 million miles from the Earth. This was an improvement over previous estimates but it was not close to the currently accepted value of 93 million miles. Clearly Kepler's estimate for the size of the Solar System was too small, but better than any other previous value.

In the *Epitome Astronomica Copernicae*, Kepler wrote about his views of the Universe. He claimed the Sun is at the center of the entire Universe and that the planets revolve around it. Because the stars have different brightness's he reasoned that they were at different distances from the Earth. He thought they were very far away and lay within the sphere of the stars. Because space could not exist without objects to occupy it, he also thought that the stars were not infinitely far away. Based on his believe in actual planetary spheres Kepler concluded that the outer boundary for the stellar sphere was also crystalline in nature and was the actual edge of the Cosmos. It can be seen from these arguments that Kepler believed in literal crystalline spheres and the actual existence of the regular solids that held the planetary spheres in place.

In the last years of Kepler's life he began work on the one remaining task, completion of the *Rudolphine Tables*. He and Tycho had planned this work during their short time together in Prague. Again Tycho's heirs continued to cause Kepler trouble by claiming that they owned Tycho's observational data. In 1625, while Kepler was working on the tables, Emperior Ferdinand again started persecuting Protestants. Because of this and the poor printing facilities available in Linz, Kepler returned to Tubingen where the *Rudolphine Tables* were finally published in 1628. After publication of the *Rudolphine Tables* Kepler moved to Duchy of Sagan in Silesia. Here he married Susanna Bartsch, the daughter of the mathematician Jacob Bartsch. With war raging everywhere in Europe during 1630 Kepler was having financial problems. So he left his family on a trip to collect money that was owed to him. At the town of Regensburg he collapsed and died on 15 November 1630.

In 1634 Kepler's son, Ludwig, published one last piece of work by his father nearly four years after Johannes had died. While Kepler was still in Prague he had begun writing the first known science fiction story called *Somnium* (*The Dream)*. The first draft was completed in 1608, but Kepler lost interest in the book and did not return to it for twenty years. The story is basically an attempt to defend the Copernican theory of the universe. In it the main character, Duracotus, takes a trip to the Moon. Kepler describes the discomforts that Duracotus experienced while in flight. He wore a special apparatus that attached to Duracotus's nose in order to have air to breathe. He also tells how Duracotus would have self-attraction that would cause his arms and legs to fold up against his body. This is a rather accurate description of gravity before gravity was even known. Lear[12] states that Kepler describes "the problems of a moon voyage succinctly with solutions amenable to the laws of physics." Duracotus walked on the Moon and talked to Moon creatures before returning to the Earth. It is at this point that Kepler was inconsistent with the fictional aspects of his writing. His character, Duracotus often spoke as an Earth native instead of as a visitor to the moon.[13] From this work it can be seen that Kepler was a man ahead of his time.

Modern astronomers still use Kepler's Laws and equations given in the *Rudolphine Tables* to calculate planetary positions. These laws are so general that they can be applied to any gravitationally orbiting objects such as comets, meteors, and binary stars. Kepler stood between Copernicus and Newton and may have been the most brilliant of the three. Kepler was one of the giants upon which Newton stood.

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[12] John Lear, Kepler's Dream (Los Angeles, CA: University of California Press, 1965), p. 52.
[13] Ibid. , 67.