Module 3: Historical Astronomy
Topic 2: The Age of Astronomy

The Age of Astronomy was marked by the struggle to understand the placement of Earth in the universe and the effort to understand planetary motion. Behind this struggle were several notable astronomers who helped to change the way humans' thought of the universe and their place within it.

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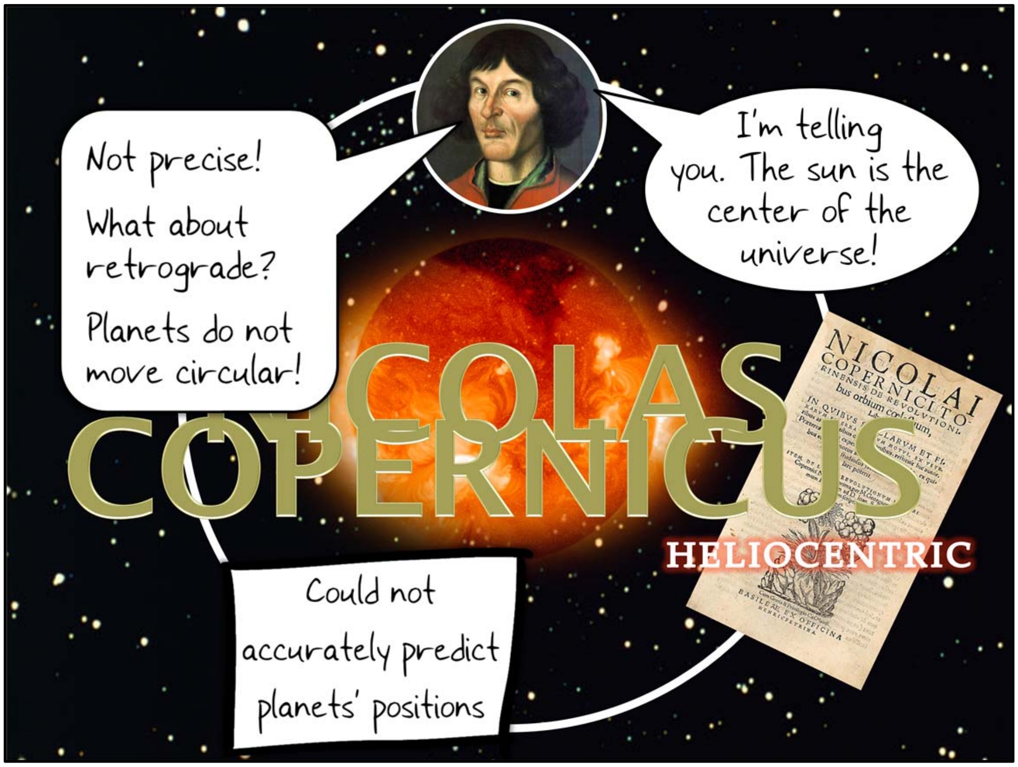

Born in Poland in 1473, Nicolas Copernicus is most famously remembered for his idea that the Sun, not the Earth, is the center of the Solar System. For more than one thousand years, astronomers had adopted the Ptolemaic model, or geocentric, Earth-centered model. Because of the radical nature of his work, Copernicus waited a very long time in his life to publish his findings. One year before his death in 1543, he published *On the Revolutions of the Heavenly Spheres*. Found within this work was his heliocentric, or Sun-centered model, which stated that the Sun belonged at the center of the universe and the Earth orbited the Sun. Listed below are the reasons why Copernicus did not like the geocentric model.

1. The geocentric model was not precise.
2. The geocentric model could not explain the retrograde motion of planets like Mars and Jupiter.
3. The true motion of planets is not circular.

The new heliocentric model was not without its own flaws. The model that Copernicus suggested could not accurately predict the positions of the planets, so astronomers would still have plenty of work to completely and accurately map the planets' positions.

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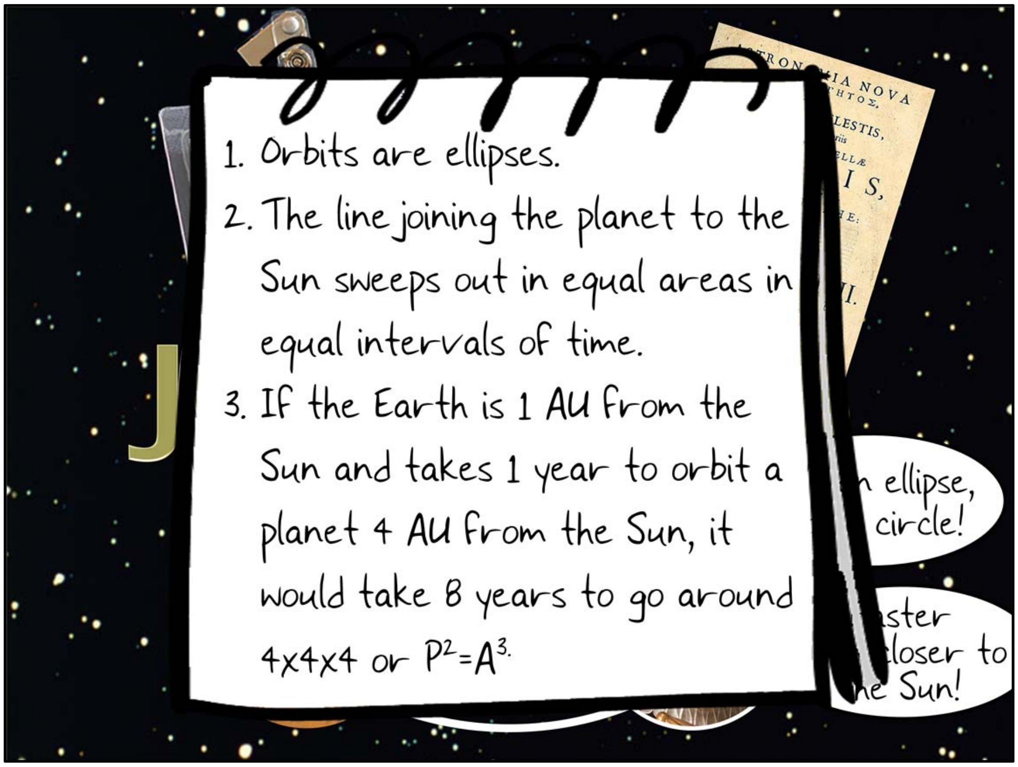
Tycho Brahe made all of his observations without the aid of a telescope because the telescope had yet to be invented. Not only was he well known for his observations, he was also well known for his vanity. Once Brahe was involved in an argument over the legitimacy of a mathematical formula. This argument led to a swordfight, during which Brahe lost the bridge of his nose. Brahe made several prosthetic nosepieces, with the most notable being made from silver and gold. For this, Brahe was known as the man with the golden nose.

Brahe was a wonderful observer of space. In 1572, Brahe observed an object in the sky. It turns out that this new object was a supernova. He published his findings in the book, *De Stella Nova* in 1573. This object is now known as Tycho's Supernova.

His observation of this supernova brought him great notoriety. Because of his observation, King Frederick of Denmark built Brahe his own observatory. The observatory was named Hveen, and it had six separate towers all devoted to astronomy. This observatory became a center for astronomy, and Brahe built oversized instruments to accurately measure the planets. With his oversized instruments and very accurate measurements, Brahe believed that both the Ptolemaic and Copernican models were inaccurate. Brahe devised his own Tychonic Model that had all of the planets, with the exception of Earth, orbiting the Sun.



Johannes Kepler was hired by Tycho Brahe as his assistant while working for the Holy Roman Emperor. One of Kepler's jobs was to analyze the data that Brahe collected over his many years of observation. Soon after Kepler's hiring, Brahe collapsed and died suddenly, leaving his works in Kepler's possession.

Kepler studied the motion of Mars. Using the data from Brahe, he discovered that Mars orbited the Sun in an ellipse and not a circle. Kepler also discovered that the planets do not move with uniform speed along their orbits. As the planets get closer to the Sun, they move faster than when they are further away. Kepler published his findings in his book, *New Astronomy*, in 1609. From this book, three laws of planetary motion are devised.

1. The orbits of the planets are ellipses, with the Sun at one focus.
2. The line joining the planet to the Sun sweeps out in equal areas in equal intervals of time. This means that the planet moves quickly when it is close to the Sun and slowly when it is farther away.
3. The squares of the sidereal periods are proportional to the cubes of the semi-major axes. This means that if Earth is 1 AU from the Sun and takes one year to orbit a planet four AU from the Sun, it would take eight years to go around 4x4x4 or $P^2=A^3$.

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Galileo Galilei is commonly given credit for inventing the telescope in 1609. In fact, it was not Galileo but a Dutchman named Hans Lippershey who invented the telescope. Galileo did use the telescope and built working examples of the telescope to study the planets and moons of Jupiter. With his newly built telescopes, Galileo discovered spots on the Sun and craters on the Moon. This went against the church's views at the time that the heavens were perfect.

Galileo discovered that the moons of Jupiter followed Jupiter as the planet moved. This implied that the Earth's moon was also orbiting Earth. According to the geocentric models, everything orbited the Earth. If Jupiter's moons orbited Jupiter, then this would prove the model incorrect. Galileo also discovered that Venus has phases much like our Moon does. The geocentric model would not account for the phases of Venus.

Galileo published his findings in a controversial book titled, *Dialogo Dei Due Massimi Sistemi*, or Dialogue Concerning the Two Chief World Systems. The book sold out by 1632, and the Roman Inquisition of the Catholic Church ordered the sale of the book to cease. For writing and publishing the book, Galileo was sentenced to life imprisonment. He was confined to his villa for the next ten years where he eventually died.

It was Sir Isaac Newton who was able to show that Kepler's Laws of Planetary Motion better explained the heliocentric model. These motions are better known as Newton's Laws of Motion, and were published in his work *Principia* in 1687. With this set of laws, Newton remade astronomy into an analytical science in which astronomers could measure the positions and motions of celestial bodies, calculate gravitational forces acting on them, and predict future motions. Newton's Laws of Motion include the following statements:

1. Every mass or body, be it at rest or moving, will not alter its present state unless acted upon by an external force. This is known as the law of inertia.
2. The change in direction or speed of an object is proportional to the amount of force acting on that body. The change in motion is also in the same direction to which the force is acting. This is displayed through the equation F=ma.
3. For every action, there is an equal but opposite reaction.