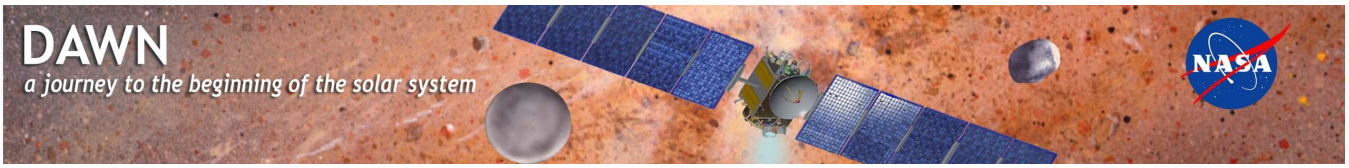
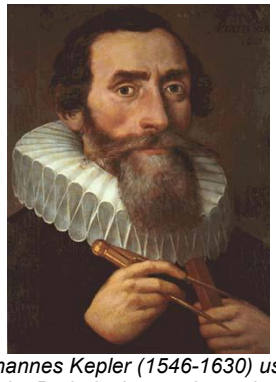


History and Discovery of Asteroids

Between Jupiter and Mars, I Place a Planet

FLASHBACK—EARLY ASTRONOMY

Astronomers that lived after **Copernicus**[1] based their work on his sun-centered arrangement of the planets. **Tycho Brahe**, a 16th century Danish astronomer working in Germany, spent 26 years observing the planets and making thousands of precise, systematic measurements of the planetary movements. Then his assistant, **Johannes Kepler**, applied mathematics to Brahe's measurements in order to calculate the planets' orbits. When Kepler analyzed Brahe's data, he discovered that there was an unusually large empty space between Jupiter and Mars. The space was so large that Kepler thought there was something missing. In 1596, he wrote, "Between Jupiter and Mars, I place a planet." Kepler thought that there must be an undiscovered planet between the orbits of Mars and Jupiter.



Johannes Kepler (1546-1630) used Tycho Brahe's data to determine the laws of planetary motion.

Early astronomers
- made measurement observations
- used mathematics to analyze data
- made scientific models

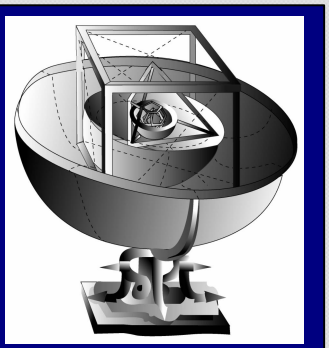
Kepler Influenced by Copernicus

Michael Maestlin, Kepler's mathematics teacher, was one of the earliest astronomers to accept Copernicus' sun-centered theory, but he did not share his acceptance openly. Maestlin taught only the accepted Earth-centered solar system in his regular university lectures. However, Maestlin described the Copernican system in special classes that Kepler attended. Even though Copernicus's theory made sense to Kepler, he did not tell anyone that he agreed with it.

Kepler's Scientific Contributions

Like other early astronomers, Kepler was an amateur astronomer. As a profession, Kepler became a mathematics professor at the Protestant seminary in Graz in 1594. He was also appointed district mathematician and calendar maker. In his spare time, he wrote science fiction novels.

In 1597 Kepler published his first important work, *Misterium Cosmographicum* ("*The Cosmographic Mystery*"). It contained his mathematical model designed to explain the **relative distances** of the planets from the Sun in the Copernican system. He described the distances as being determined by the five classical planets. In his model, each planet's orbit encircled one solid and was surrounded by another.



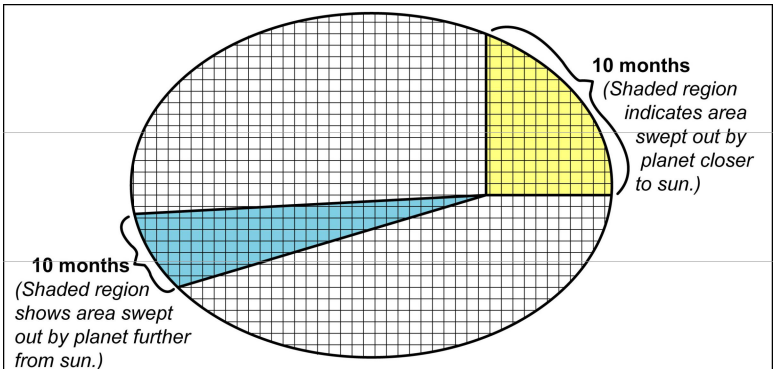
Kepler's model to explain the relative distances of the planets from the Sun in the Copernican System.

Scientific models are often used to predict behavior or properties that have not yet been observed, but models have limitations. Kepler's model was remarkably accurate.

Learn More About
Scientific Models

Kepler's Laws of Planetary Motion

Kepler continued to explore his model. He used both physics and mathematics to form his **planetary orbit** laws. The laws were published in "New Astronomy" in 1609. His first law stated that planets move in **elliptical orbits** with the sun as one of the **foci.** His second law said that a planet sweeps out or covers equal areas in equal times as it travels in its orbit. There are 90 yellow squares and 90 blue squares in the diagram below. So these areas are equal even though the planet travels a longer distance in ten months when it is closer to the sun than it does in ten months when it is further from the sun.



According to Kepler's first law, planets revolve around the sun in *elliptical orbits.* Kepler's second law of planetary motion reveals that planets orbiting the sun will sweep out equal areas in equal times. The shaded regions show the area covered by planets in orbit. Planets closer to the sun may move more quickly than planets further from the sun; however, the area covered over 10 months is the same.

[1]see "Thinking Outside the Box" Vignette

Additional Resources

To learn more about Johannes Kepler and his laws of planetary motion, visit the following Web sites:

http://es.rice.edu/ES/humsoc/Galileo/People/kepler.html
Biography of Johannes Kepler

http://www.kepler.arc.nasa.gov/johannes.html
A short biography, a list of Kepler's "firsts", and world events happening while Kepler lived and worked.

http://www-gap.dcs.st-and.ac.uk/~history/Mathematicians/Kepler.html
This biography includes details about his education, his work, and his personal life.

http://csep10.phys.utk.edu/astr161/lect/history/kepler.html
This site provides explanations of Kepler's Laws as well as an interactive "Kepler's Laws Calculator."

http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/circmot/ksl.html
Multimedia Physics Studio features an animation of Kepler's Second Law.

http://www.jpl.nasa.gov/webcast/genesis.html
NASA's Genesis mission offers the Webcast, *Kids Get Down with Gravity,* which helps to illustrate Kepler's Third Law.

Questions relating to Between Jupiter and Mars, I Place a Planet

1. Tycho Brahe and Johannes Kepler worked together as they studied the solar planetary movements. Describe what part of the work each of them did.
2. How many years did Brahe make planetary movement measurements?
3. How many years lapsed between the time Copernicus proposed his Sun-centered model and when Johannes Kepler decided there should be a planet between Jupiter and Mars?
4. Why would Kepler's professor still teach Ptolemy's model if he believed in the sun-centered theory?
5. How did Kepler use his understanding of mathematics to form his planetary orbit model?
6. How did Kepler use his mathematics and physics background to describe his planetary motion laws?
7. Kepler's Second Law of Planetary Motion indicated that planets traveled faster at some points of the orbits than others. Where did planets travel the fastest—away from the Sun or close to the Sun?
8. How might you use an image or animation to explain the Laws to your classmates? There are some helpful images/animations available at:
   http://csep10.phys.utk.edu/astr161/lect/history/kepler.html
   http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/circmot/ksl.html