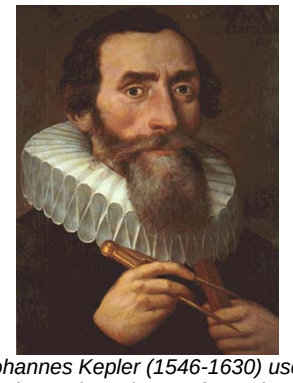
# Between Jupiter and Mars, I Place a Planet



http://kepler.nasa.gov/johannes/

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

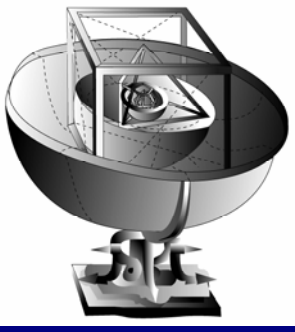
Astronomers living after **Copernicus** proposed his sun-centered or **heliocentric** theory (see "Thinking Outside the Box") used his arrangement of the planets as the basis for their ideas that large spaces existed between the orbits of the planets. **Tycho Brahe**, a 16th century Danish astronomer working in Germany, spent 26 years making thousands of precise, systematic measurements of the planetary movements. Brahe's mathematician assistant, **Johannes Kepler**, discovered that there was an extraordinarily large empty space between Jupiter and Mars as he was using Brahe's data to determine the shape of planetary orbits. The space was so large, in fact, that it "offended Kepler's sense of proportion." In 1596, he wrote, "Between Jupiter and Mars, I place a planet." Kepler had come to the conclusion that there must be an undiscovered planet between the orbits of Mars and Jupiter.

## Kepler Influenced by Copernicus

**Michael Maestlin**, Kepler's mathematics teacher, was one of the earliest astronomers to accept **Copernicus's** sun-centered theory; however, he taught only the Ptolemaic **geocentric** system in his regular university lectures. Why? At that point, Copernicus's theory wasn't widely accepted. Maestlin introduced a few of his students to the technical details of the Copernican system in special "graduate seminars." Kepler, who attended these extracurricular classes, later recalled that it was at this time that he became a Copernican for "physical or, if you prefer, metaphysical reasons." Even though Copernicus's theory made sense to Kepler, he did not make his acceptance public.

## Kepler's Scientific Contributions

When Kepler became a professor of mathematics 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.



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

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 regular solids – the known planets. In his model, each planet's orbit encircled or was **circumscribed** about one solid and **inscribed** in or was surrounded by another. Scientific models are often used to predict behavior or properties that have not yet been observed, but models also have limitations. Kepler's model was remarkably accurate.

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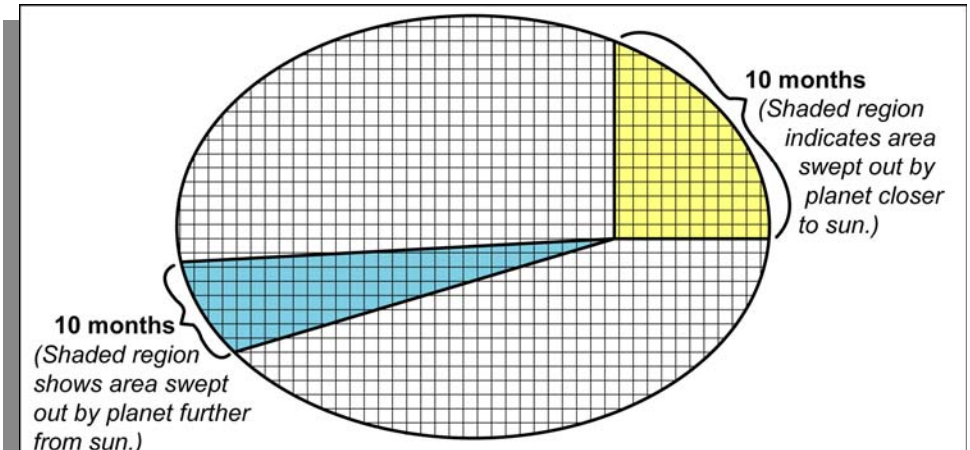
**Scientific Models**

## Kepler's Laws of Planetary Motion

Kepler continued to explore his model, incorporating physics and mathematics into astronomy. In 1609, his laws regarding **planetary orbits** were published in *Astronomia Nova* ("New Astronomy"). The first law stated that planets move in **elliptical orbits** with the sun as one of the **foci**; and the second law stated that a planet sweeps out 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.

## Additional Resources

### Web Sites

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

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

http://kepler.nasa.gov/johannes/
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 Kepler's education, work, and personal life.

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.

**Print Resources**


Cousins, F.W. (1972). *The solar system*. New York, NY: Pica Press.

Grunn, B. (1991). *The timetable of history – A horizontal linkage of people and events*. Simon & Schuster, Inc.

McSween, H.Y. (1999). *Meteorites and their parent planets***.** Cambridge; NY: Cambridge University Press.

Peebles, C. (2000). *Asteroids: A history*. Washington, DC: Smithsonian Institution Press.

Roth, G.D. (1962). *The system of minor planet*. Princeton, NJ: Company Inc.

Schorn, R.A. (1988). *Planetary astronomy*. College Station, TX: Texas A&M University Press.