Ch 22 Origin of Modern Astronomy

• Hundreds of years ago it was thought the Earth was the center of the universe.

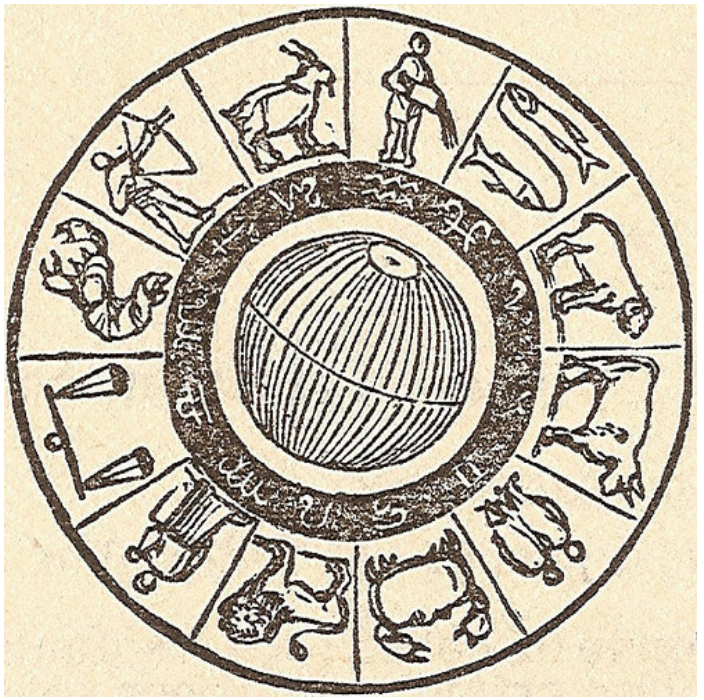
• Historically, since the dawn of time ancient societies and supporters of aristotelian philosophy, (medieval science, educational, and religious beliefs following Aristotle's theories) have looked up into the night sky and have used the stars and planets to make calendars and have wondered.

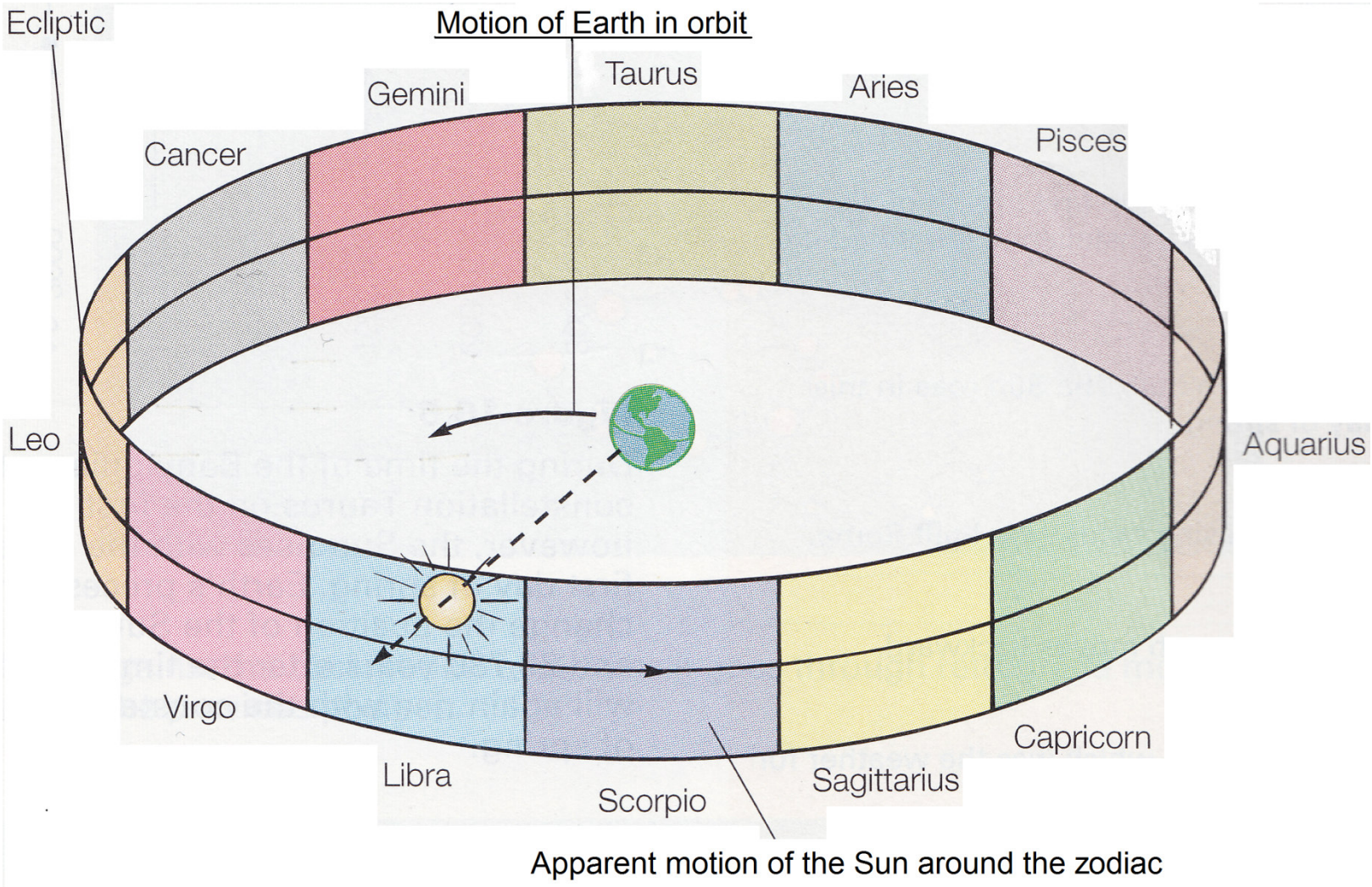
Ancient Astronomy

• Observing the sky occurred in many early civilizations. Neolithic people in Britain around 2600 B.C. built a megalithic ruin known as **Stonehenge** to track the Sun and Moon in order to know the summer and winter solstice and the spring and autumn equinox.

Babylon

- As early as 2000 B.C. the Babylonians on clay tablets kept track of time by dividing the year into 12 months, with 7 days to a week, and 360 days to a year.
- The Babylonians observed the Sun, Moon and five planets to move across the night sky only along a certain path on a dome or *celestial sphere*.
- The seven celestial bodies moved independently of the stars and only within a narrow band across sky.
- The Sun's movement in the center of the band appears to move among the stars is called today the **ecliptic** (the Sun's path across the sky).
- They also imagined the arrangements of certain stars to be in the shapes of some mythical god, object or animal. These imagined patterns of stars are called **constellations**.
- **Constellations** are twelve equal divisions of the ecliptic through which the Sun passed in monthly succession.
- These twelve constellations are called the **zodiac**, which means "circle of animals."

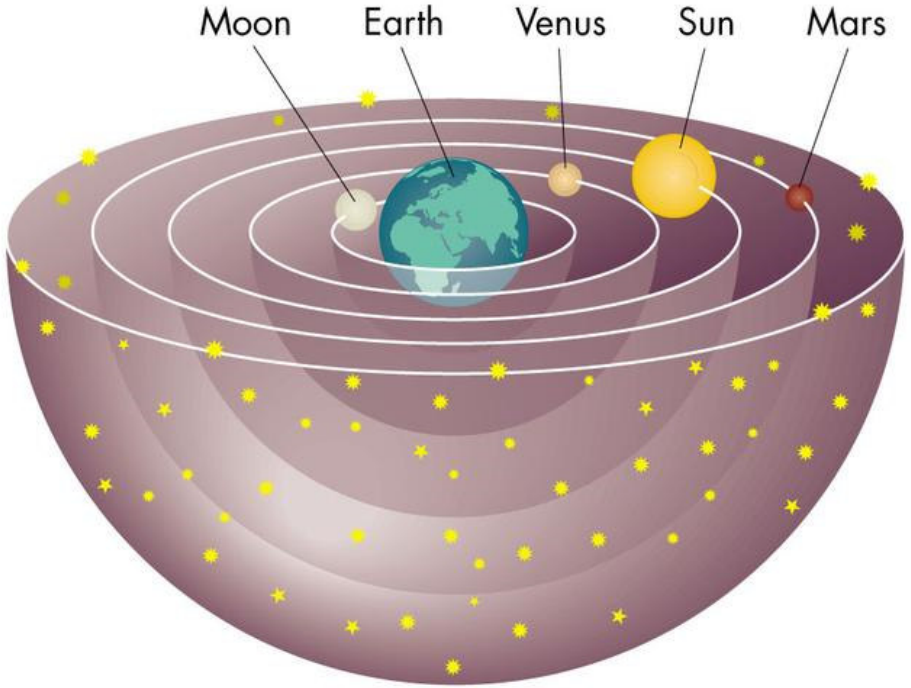




The Sun, Moon, and planets move across the constellations of the zodiac, with the Sun moving around all twelve constellations during a year. From Earth, the Sun will appear to be "in" Libra at sunrise in this picture. As Earth revolves around the Sun, the Sun will seem to move from Libra into Scorpio, then through each constellation in turn.

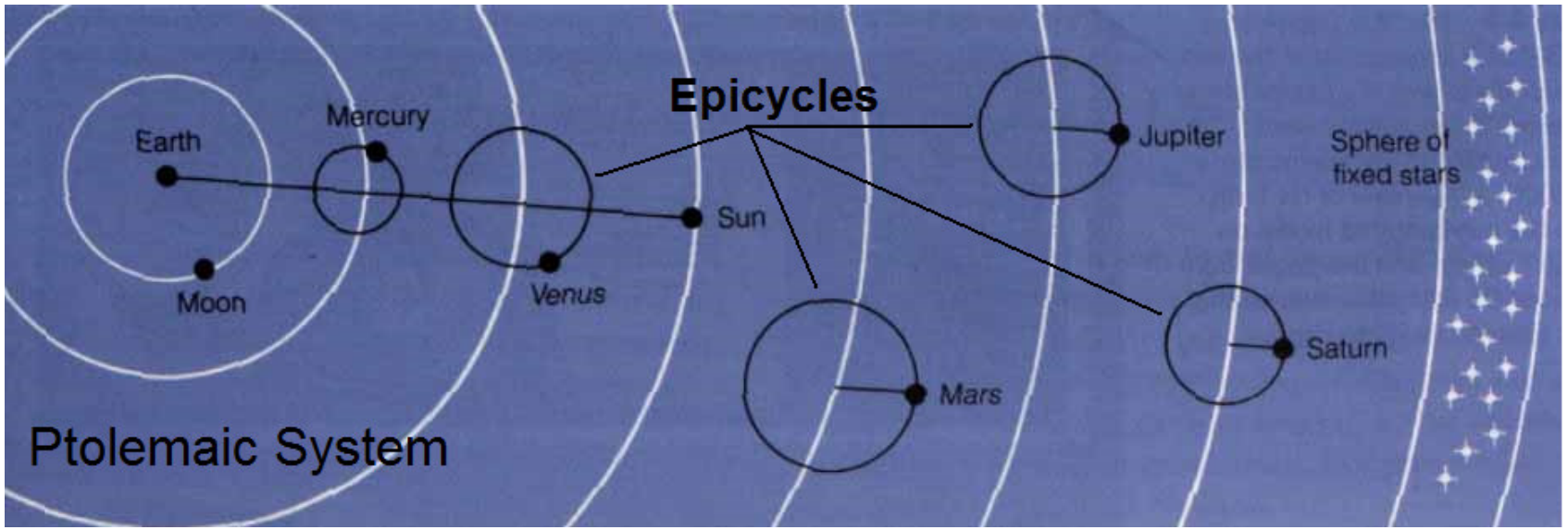
Ancient Greeks

- The Greeks obtained some of their understanding from the Babylonian belief in a geocentric concept.
- **<u>Geocentric model of the universe is the Earth is in the center of the universe</u>** and the Sun, planets, Moon, and stars were attached to shells or celestial sphere and turns around a fixed Earth.
- The five bodies, (Mercury, Venus, Mars, Jupiter and Saturn) that went around the Earth in not a fixed pattern. The Greeks used a Greek word "planetes" for **wanderer** to explain this occurrence.
- The Greek's theory of the universe had Earth fixed and motionless at the center. All of the planets and the Sun move around Earth attached to spherical shells.

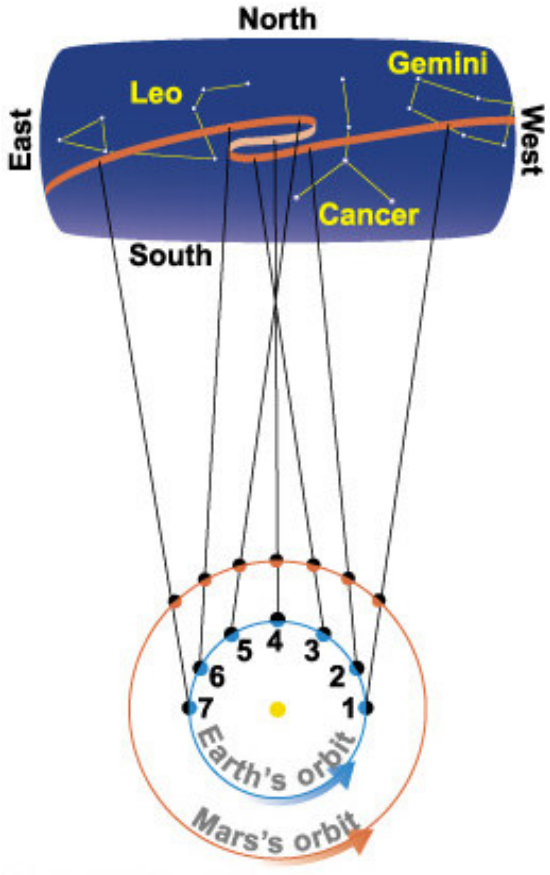


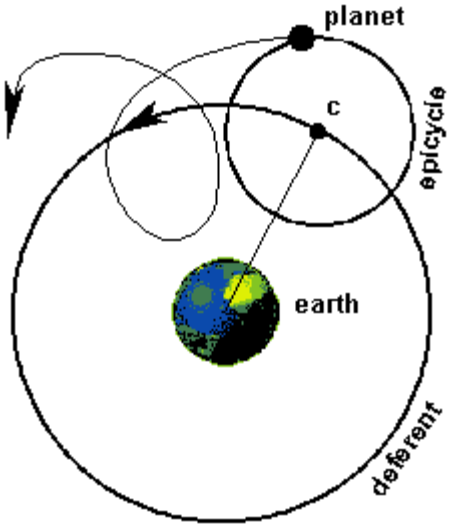
- The famous Greek philosopher **Aristotle proposed the geocentric model which meant the Earth was at the center of the universe**.
- **Aristotle concluded the Earth was round because the Earth casts a curved shadow on the Moon during a lunar eclipse**.
- His beliefs carried by the early science and religious community, (aristotelian philosophy) well into the early 1700's.
- The Greek scholar **Eratosthenes** of Alexandria, Egypt was the first person to successfully calculate the circumference of the Earth.
- He used a well at Syene, Egypt where sunlight only struck straight the bottom of the well and the angle of the shadow in Alexandria on the summer solstice.

- **Aristarchus** was the first ancient Greek astronomer to present an explicit argument for a **heliocentric** model of the solar system, placing the Sun, not the Earth, at the center of the known universe. His astronomical ideas were rejected in favor of the geocentric theories of Aristotle and Ptolemy until they were successfully revived nearly 1800 years later.
- The Roman astronomer **Claudius Ptolemy** believed the Sun, Moon, planets, and stars were attached to crystalline spheres, the planets moved in circular orbits around a motionless Earth, this is known as the **Ptolemaic System**.



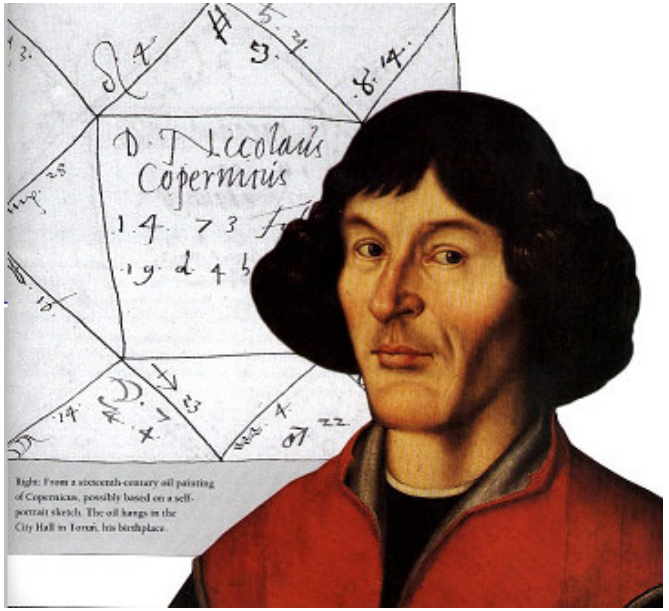
- There was a problem, planets watched over several nights moves slightly eastward among the stars, but then periodically, each planet appears to stop, reverse direction for a time, and then resume an eastward motion. This is called **retrograde motion**.
- Ancient astronomers had difficulty explaining retrograde motion of the planets. Over the course of a single night, a planet will move from East to West across the sky, like any other celestial object near the ecliptic.
- Ptolemy explained retrograde motion by saying planets moved along in smaller circles while they moved along their orbits around the Earth as **epicycles**.
- Ptolemy's theory was wrong, and for nearly 1500 years, the Ptolemaic System was accepted by astronomers and by the Church.





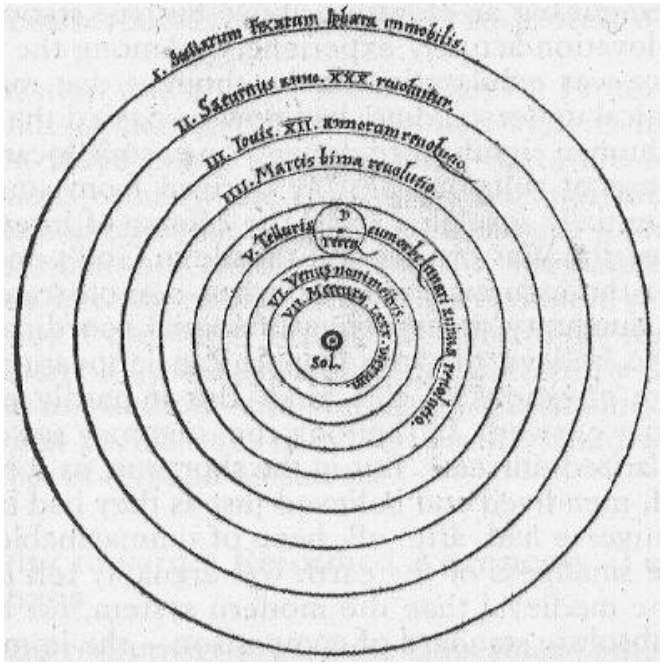
The Birth of Modern Astronomy

- The development of modern astronomy involved a break from previous philosophical and religious views. For nearly 1500 years astronomers believed in the geocentric universe. It all was about to change in1473 in what is now Poland.



Nicolaus Copernicus

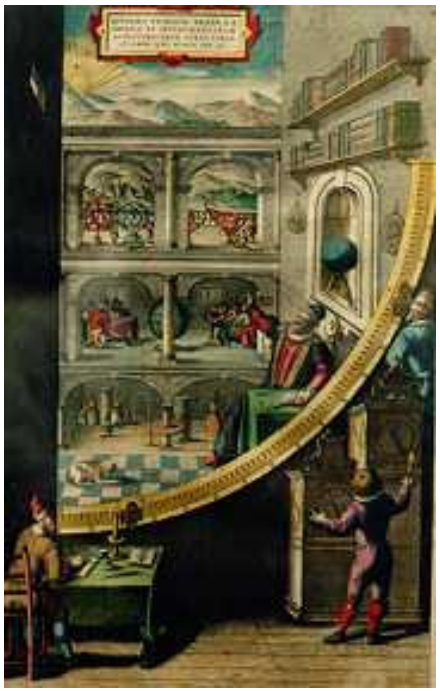
- Copernicus (1473 – 1543) was the first astronomer to formulate a comprehensive **heliocentric cosmology**, which displaced the Earth from the center of the universe. He became convinced that <u>the Earth was a planet and it revolved with the other planets around the Sun</u>. This was a revolutionary new concept that went against the views of astronomy at the time and against the views of the Church of Rome.
- Knowing this and to avoid the Inquisition, Copernicus did not finish printing his book before his death.
- His book described his ideas about his heliocentric hypothesis of the planets orbiting the Sun in **<u>uniform circles</u>**. Even though inaccurate, the Copernican Model was the beginning of the end of the Ptolemaic system.



- With the Copernican system, the Earth moves faster along its orbit than the planets that lie farther from the Sun. The Earth periodically overtakes and passes these other outer planets.
- Copernicus could explain retrograde motion without epicycles. It was elegant and simple compared to the whirling epicycles of the Ptolemaic system.
- One critical problem, the Copernican theory could not predict the positions of the planets any more accurately than the Ptolemaic system could.

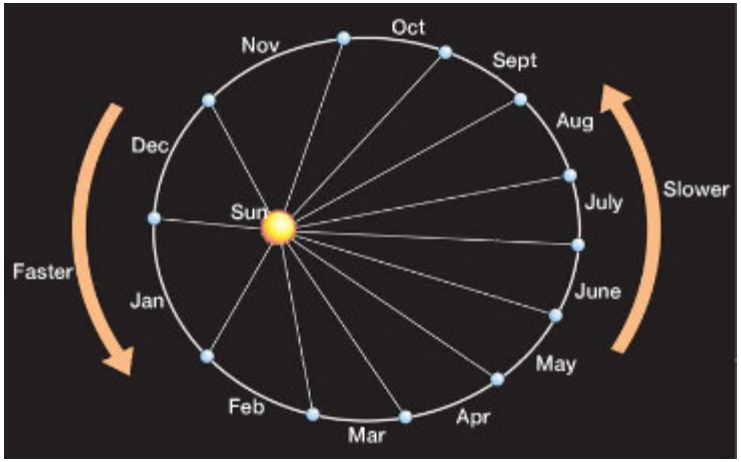
Tycho Brahe

- Tycho (1546 – 1601) was a Danish nobleman who became interested in astronomy. He built an observatory near Copenhagen to view the night sky.
- Using only instruments designed and built by himself (the telescope was not yet invented), Tycho setout for 20 years to measure the locations and document the movements of the planets.
- Tycho's observations were <u>far more precise</u> than any made previously.



Johannes Kepler

- Kepler (1571 – 1630) with a mathematical mind and a believer in the Copernican hypothesis, joined Tycho and moved to Prague, and went to work for Tycho.
- With the sudden death of Tycho in 1601, it left Kepler in a position to use Tycho's notes and books to continue his work in astronomy.
- Because Kepler was a mathematician, his triumph was the solution of the problem of the orbit of the planets. The key to his solution was the **ellipse or an elliptical orbit**.
- An ellipse is a figure drawn around two points, called **focus** which helps to determine the shape of the ellipse. The further apart the foci, the more stretched out the ellipse.
- Kepler used ellipses to describe the motion of the planets in three fundamental rules that have tested and confirmed and now referred to as natural laws, called **Kepler's Laws of Planetary Motion**.

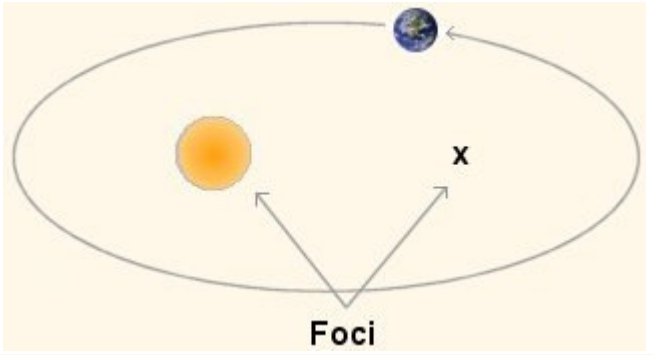


Kepler's Laws of Planetary Motion

- **Using Tycho's data, Kepler proposed the following three laws of planetary motion.**

Law 1. **The orbits of the planets are ellipses, with the Sun at one focus.**

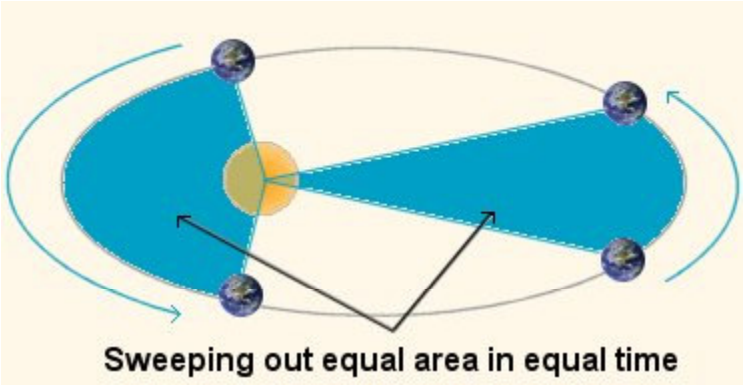
Any ellipse has two geometrical points called the foci.



Law 2. **The line joining a planet to the Sun sweeps out equal areas in equal times as the planet travels around the ellipse.**

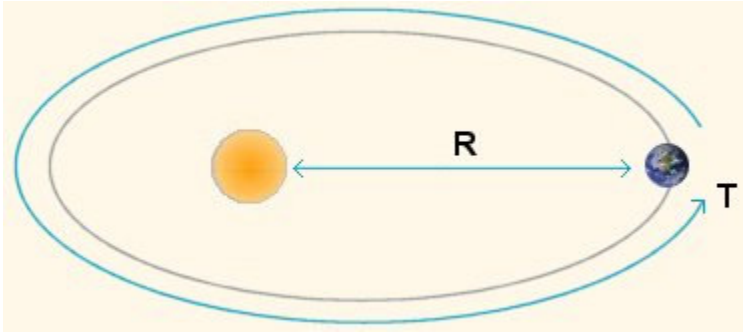
The planet moves faster when it is nearer the Sun and slower when it is farther from the Sun.

A planet moves with constantly changing speed as it moves about its orbit.

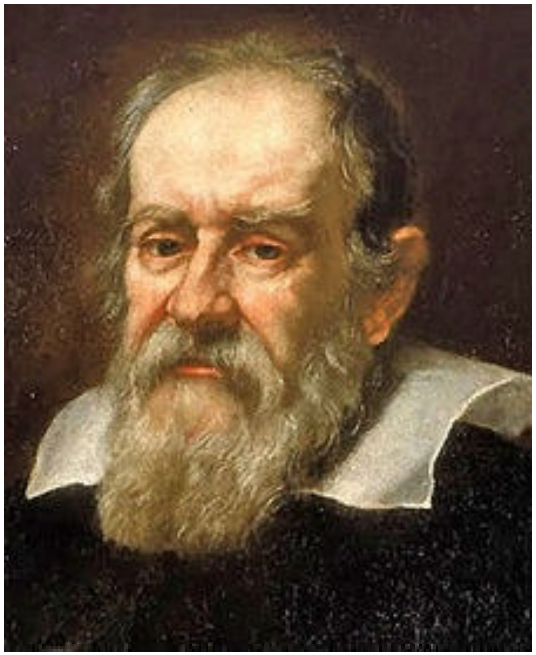


Law 3. **The square of the total time period (T) of the orbit is proportional to the cube of the average distance of the planet to the Sun (R).**

This law compares the orbital time period and radius of an orbit of any planet, to those of the other planets.



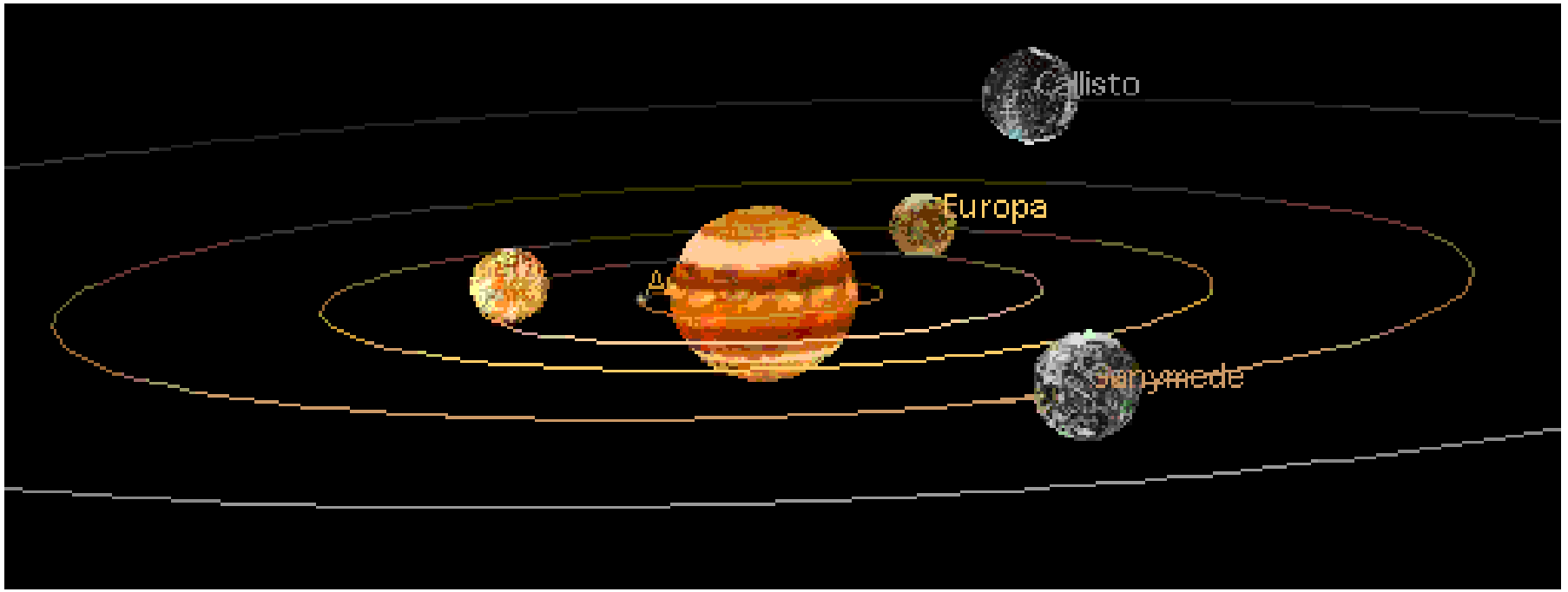
Galileo Galilei



- Galileo (1564 – 1642) was a great Italian scientist, mathematician, and astronomer of the Renaissance. He did not invent the telescope but by learning about a Dutch lens maker devised one, he built his own. By using his telescope, he made important contributions in describing the behavior of moving objects.
- He supported the Copernican model and with a letter to Kepler he admitted he did not publicly support Copernicanism to avoid criticism.
- Through his telescope he made five discoveries:
  1. Four satellites, or moons, orbiting Jupiter.
  2. The planets are circular disks, not just points of light.
  3. Venus has phases just like the moon.
  4. The moon's surface was not smooth and perfect.
  5. The Sun had sunspots or dark regions (blemishes) and is not perfect.
- With his discoveries, he rushed a small book to print , *The Sidereal Messenger* to report his discoveries.

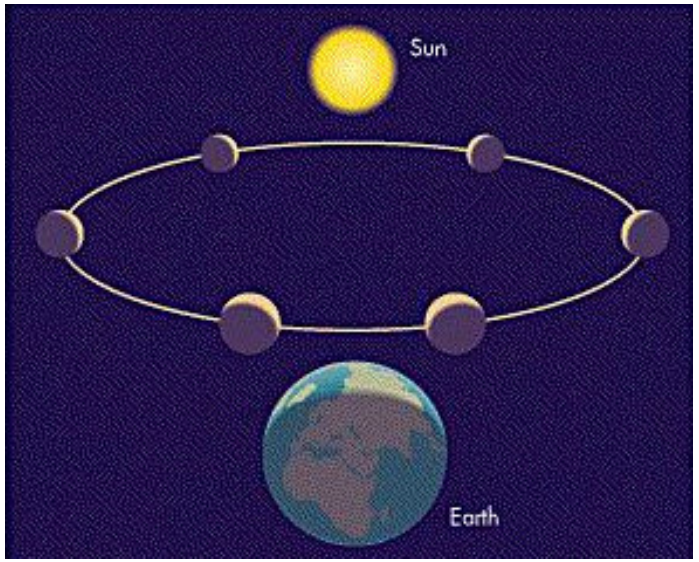
- **The four satellites, or moons, orbiting Jupiter.**

  The moons of Jupiter supported the Copernican model. Critics said Earth could not move because it would leave the Moon behind. But Jupiter moved and kept its satellites. This proved Earth too could move and keep its moon.



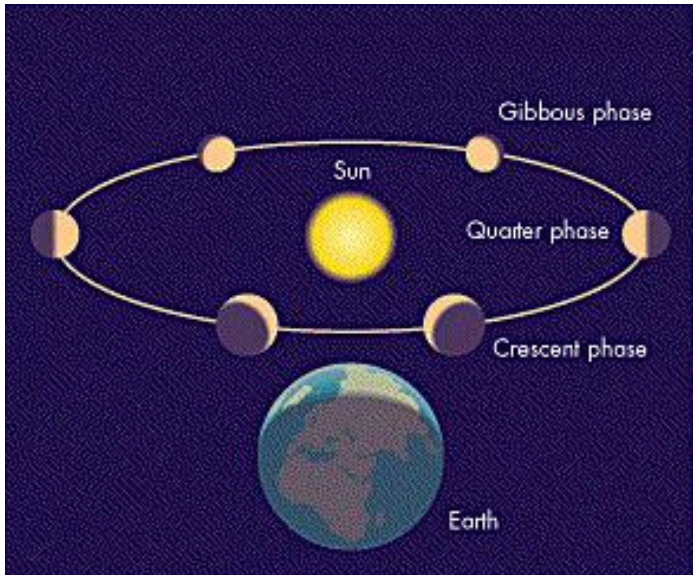
Jupiter's moons not to scale.

- Venus has phases just like the moon.
- When Galileo observed Venus, it was going through phases like the Moon. In the Ptolemaic model, Venus moves around an epicycle centered on a line between the Earth and the Sun. It would always be viewed as a crescent.
- Galileo saw Venus go through a complete set of phases, which proved that it did revolve around the Sun.



The Ptolemaic system

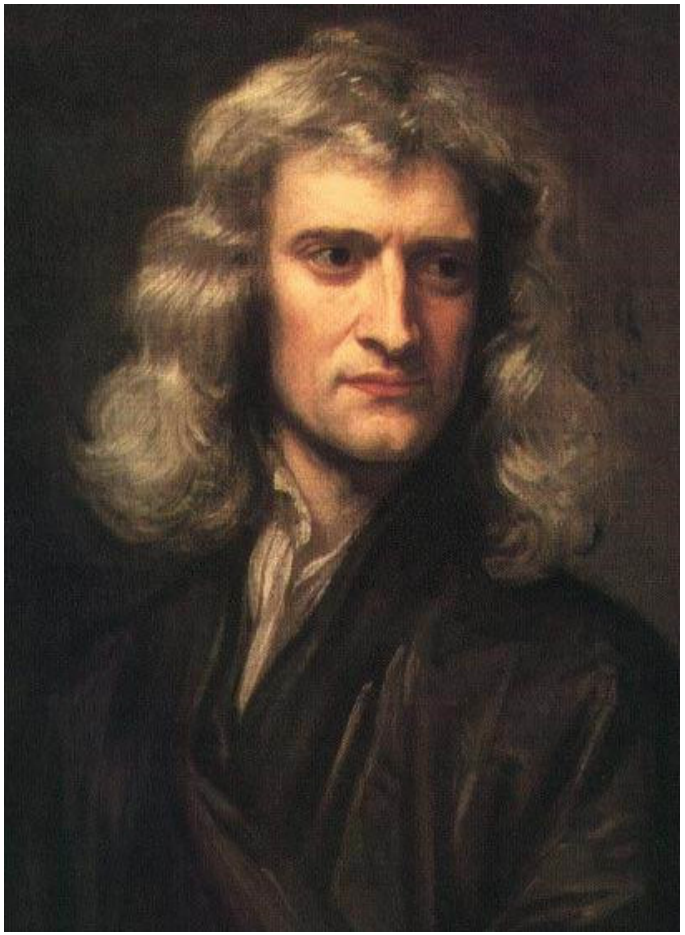
- In 1616, Galileo was told by Pope Paul V to cease the support of Copernicanism.
- In 1632, Galileo wrote a publication that supported Copernicanism. In it he showed disrespect to his friend, Pope Urban VIII, and Pope Urban ordered Galileo to face the Inquisition.
- In 1633, the Inquisition condemned him not of heresy but for disobeying the previous orders from 1616.
- The trial was not about Copernicanism. It wasn't really about the orders he got in 1616, <u>it was about that Galileo was arguing against **Aristotle's theory**</u>.



The Copernican system

The Last Piece of the Puzzle

- Copernicus proposed the correct model of the solar system.
- Tycho made precise observations of the planets.
- Kepler discovered planet's orbits were ellipses and the three laws of planetary motion.
- Galileo, with the telescope made discoveries that supported the Copernican model.
- With all of the discoveries there was still one item that was still missing: **motion**, what controls it and how it relates to objects moving is space. To answer that, it fell to Sir Isaac Newton.



Sir Isaac Newton

- Newton (1642 – 1727) described a force that holds the moon in orbit around Earth. The outcome of his work was **his three laws of motion and gravity**, and the important impact on the future of astronomy.

- According to Newton, every body in the universe attracts every other body with a force that is directly proportional to their masses and inversely proportional to the square of the distance between their centers of mass.
- **The force that gravity exerts on an object is mass.**
- Also, gravitational force decreases with distance. The further apart two objects are, the less gravitational attraction.
- With that, the greater the mass of the object, the greater is its gravitational force.
- Weight is not the same as mass. Weight is the force of gravity acting upon an object.
- If it was not for gravity, a planet would move in a straight line into space. Gravity causes the planet to fall toward the larger mass object. The combination of straight line motion and gravity produces the curved elliptical orbit of a planet.