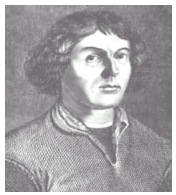
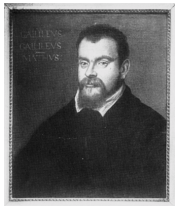
Copernican Revolution

- Motion of the sun & planets
- Ptolemy's *Almagest*
- Copernicus' *de Revolutionibus Orbium Caelestium, (Concerning Revolutions of the Heavenly Spheres),* 1543
- Galileo refutes Ptolemy with his observations of the phases of Venus



Nicolai Copernicus
(1473-1543)



Galileo Galilei
(1564-1642)

Wood, paper; length: 1360mm, lens diameter 26mm
http://galileo.imss.firenze.it

Copernican Revolution: questions on reading assignment

1. Retrograde or normal motion of a planet concerns
   a. whether it rises in the east or west
   b. its motion with respect to the stars behind it.
2. Ptolemy (200AD) believed
   a. The earth moved around the sun once a year
   b. The sun moved around the earth once a year
   c. The earth moved around the sun once a day
   d. The sun moved around the earth once a day
3. We now know… (Use same answers as in #2.)

Motions of the sky

- To make his model, Ptolemy (about 100-170 AD) used observations that you can make without a telescope.
- What motions have you observed?

Motions of the sky

What motions have you observed?

A. Night & day. Sun rises & sets.
B. Stars rise & set.
C. Different stars are seen at different times of the year. Eg., Orion is seen in early evening in March. The "Summer Triangle" is seen in early evening in the summer.
D. Venus is seen just before sunrise or just after sunset; it is never seen at midnight.

1. What model explains observation A?
   a) The sun moves around the earth.
   b) The earth moves around the sun.
   c) The earth turns.
2. What model explains observation B? Use same foils.
3. What model explains observation C? Use same foils.

Celestial sphere

- Ptolemy's celestial sphere
  - Stars are on the celestial sphere.
  - Sun is on a separate sphere.
  - Both spheres turn around the earth once a day. The sun's path is a circle.
  - The sun's sphere moves a little each day.
- Copernicus' celestial sphere
  - The stars are so far away that they appear to be on a distant sphere.
  - Earth turns once a day counterclockwise.
  - Earth moves around the sun.

1. Which constellation(s) are high in the sky at midnight on 1/21?
   a. Cancer
   b. Sagittarius
   c. Aquarius
   d. Taurus
2. Which constellation(s) are high in the sky at noon on 1/21, if you turned off the sun? Same foils.
3. Which constellation(s) are high in the sky at 6am on 1/21

Celestial sphere

- Ptolemy's celestial sphere
  - Stars are on the celestial sphere.
  - Sun is on a separate sphere.
  - Both spheres turn around the earth once a day. The sun's path is a circle.
  - The sun's sphere moves a little each day.
- Copernicus' celestial sphere
  - The stars are so far away that they appear to be on a distant sphere.
  - Earth turns once a day counterclockwise.
  - Earth moves around the sun.

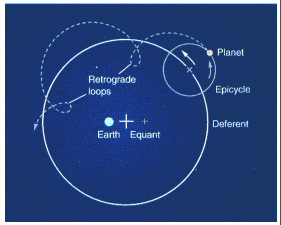
1. Which constellation(s) are high in the sky at midnight on 6/21?
   a. Cancer
   b. Sagittarius
   c. Aquarius
   d. Taurus

Motion of planets: Ptolemy's *Syntaxis (Almagest)*, 140AD

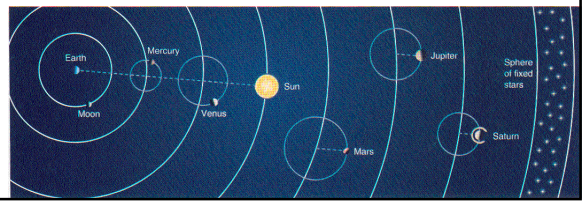
- Motion of the planets was the big unsolved problem for astronomy for over 1400 years until 1630
- With respect to the stars, planets usually move eastwardly from night to night.
  - Easy to explain for Ptolemy: Just as sun is on a separate sphere and its path is a circle, each planet has its own circular path.
- Sometimes they move westwardly with respect to the stars. (Called retrograde motion.)
  - Tough to explain.
- Aristotle's dictum: Heavenly objects move in the most perfect way. Circle is most perfect shape. Earth is at the center.

Motion of planets: Ptolemy's *Syntaxis (Almagest)*, 140AD

- With respect to the stars, planets usually move eastwardly from night to night. Sometimes they move with retrograde motion.
- Aristotle: Heavenly objects move in a circle centered on Earth.
- Ptolemy's model
  - Circular, Earth-centered motion
  - Planets are on a deferent & epicycle.



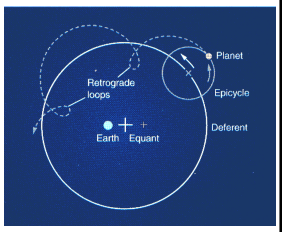
epicycle

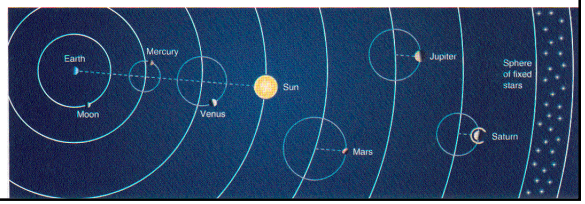


Blue figures are from Seeds, *Horizons: Exploring the Universe.*

Motion of planets: Ptolemy's *Syntaxis (Almagest)*, 140AD

- Added feature to explain why Venus & Mercury are always seen near sunset or sunrise.
- Ptolemy's model
  - Circular, Earth-centered motion
  - Planets are on a deferent & epicycle.
  - Deferent for Mercury & Venus is stuck on a line between Earth & sun.

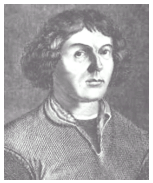




epicycle

Blue figures are from Seeds, *Horizons: Exploring the Universe.*

Copernicus proposed the idea that sun is at center

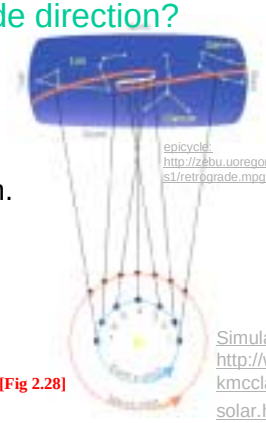


WE ARE HERE!

- Copernicus proposed that each planet is on circular orbit about sun.
  - Simpler than Ptolemy's model
  - Accuracy is worse than Ptolemy's model
  - Model violates Aristotle's "truths"
    - Heavenly objects, being perfect, move in a circle, which is the perfect shape.
    - The earth is stationary at the center.
    - Heavenly objects move at constant speed.
- Copernicus wrote *de Revolutionibus Orbium Caelestium, (Concerning Revolutions of the Heavenly Spheres)*, 1543, published after his death.

Why do planets sometimes move in retrograde direction?

- Earth moves in orbit around sun.
- The other planets move on their own orbits around the sun.



epicycle: http://zebu.uoregon.edu/textbook/images1/retrograde.mpg

[Fig 2.28]

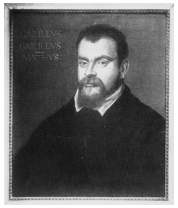
Simulation (web) http://web.cuug.ab.ca/~kmcclary/ORRERY/fastsolar.html

Simulation shows why this really happens. Click "Center", "Earth".

Simulation (local)

Galileo (1610) invents telescope

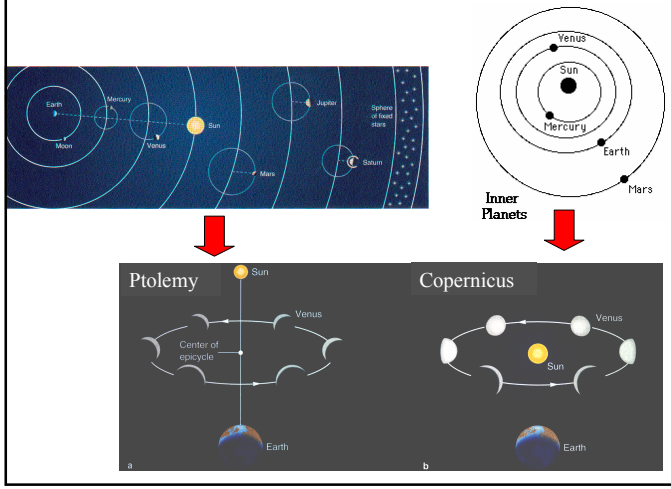
- Discoveries
  - Milky Way is made of myriads of stars.
  - Phases of Venus, disprove Ptolemy's geocentric model.
  - Craters, maria on Moon.
  - Rings of Saturn
  - 4 Moons orbiting Jupiter



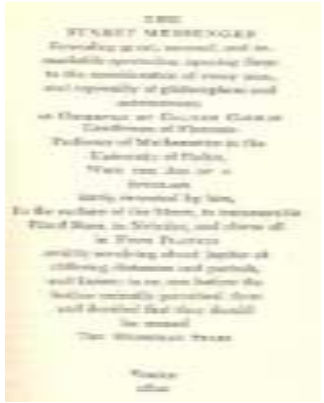
Galileo Galilei (1564-1542)

Galileo's telescopes: ~1" in diameter x 24-30" long

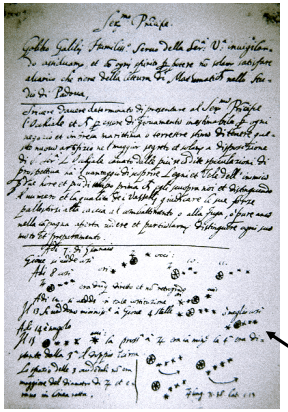
Galileo saw the phases of Venus



Starry Messenger



Galileo saw 4 moons orbiting Jupiter



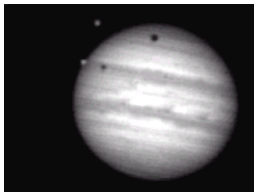


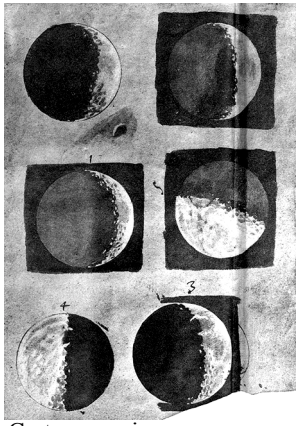
Image through modern telescope showing 2 of Galileo's satellites and their shadows

Observing notes

What Galileo Saw:

The milky way = jillions of stars

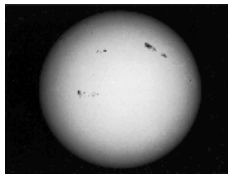
More Galileo discoveries



Craters, maria on moon

Galileo's sketch.. 1616

Rings of Saturn



Sunspots

Questions on reading

1. When Kepler was a college student, the most accurate description of the motion of planets uses the terms
   a. Velocity, position, & acceleration
   b. Circular orbits
   c. Elliptical orbits
2. Same question
3. Today the most accurate description of the motion of planets uses the terms
   a. Velocity, position, & acceleration
   b. Circular orbits
   c. Elliptical orbits