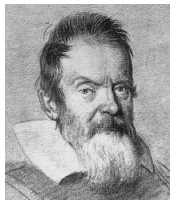
January 19

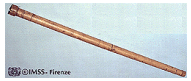
- First homework
  - http://angel.msu.edu
    - Open "lessons" folder.
  - Start on Fri, 21st.
  - Must finish by 3:00 am, Wed, 26th.
  - Besides astronomy questions, you will register your clicker number on this assignment.
- Clicker questions now count in your grade
- The lowest 10% of your scores on clicker questions are dropped.

- **Outline**
- Galileo disproves Ptolemy's earth-centered model of the solar system (left over from 15th)
- Tyco Brahe measures the positions of the planets
- Kepler finds "Laws" describing motion of the planets.

Galileo (1610) looks at the sky with a telescope

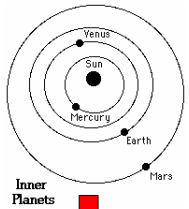


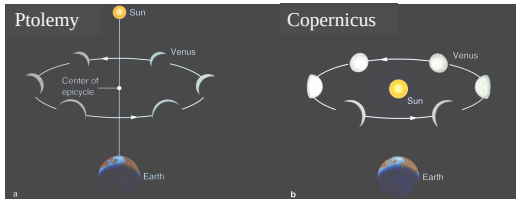
Discovered:
- Milky Way = myriads of stars.
- Phases of Venus
  - •confirmed heliocentric model.
- Sunspots.
- Craters, maria on Moon.
- Rings of Saturn
- 4 Moons orbiting Jupiter.



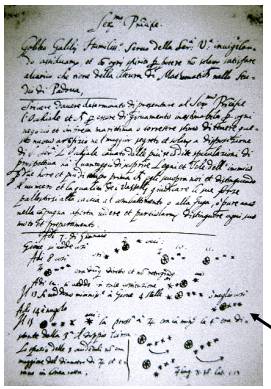
Galileo's telescopes: ~1" in diameter x 24-30" long

Galileo saw the phases of Venus





Galileo saw 4 moons orbiting Jupiter



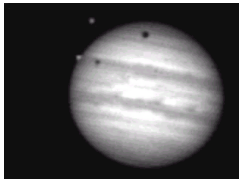
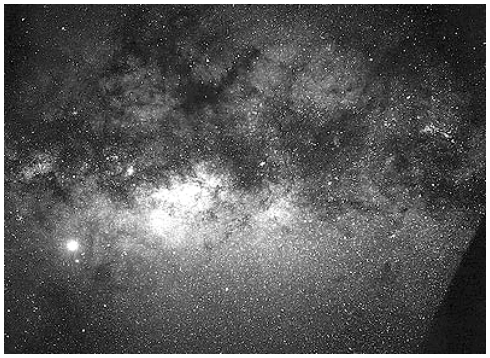


Image through modern telescope showing 2 of Galileo's satellites and their shadows

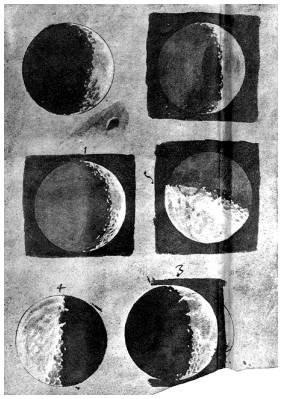
The old boy's observing notes

What Galileo Saw:

The milky way = jillions of stars



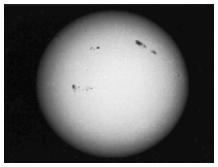
More Galileo discoveries



Craters, maria on moon

Rings of Saturn

Galileo's sketch.. 1616



Sunspots

Questions on reading Chapter 3

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

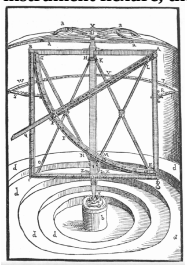
What is fake on Tycho?

Tycho Brahe's Observations

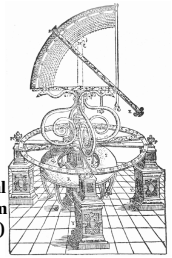
- **On Uraniborg, Tycho measured positions of the planets for 20 years**
- **Highly accurate & reliable**
  - **Accuracy limited by human eye, not by instruments. Superseded only with telescopes.**
  - **Tyco measured & compensated for instrument flexure, the biggest error.**

Uraniborg.

Great quadrant (1582)



Revolving steel quadrant, 2 m radius (1588)



Brass azimuthal quadrant, 65 cm radius (ca 1576)

Johannes Kepler analyzes Tycho's data

- Kepler was Tycho's assistant
  - 20 yrs' data on planetary motions.
  - Tycho tried to fit data with Ptolemy-like model.
- Kepler analyzed the data
  - Found 3-d orbits from 2-d positions in the sky
  - Concentrated on orbit of Mars.
  - Had to subtract off Earth's (imperfectly known) orbit.
- Discovered 3 "laws," which describe the motions of all the planets.

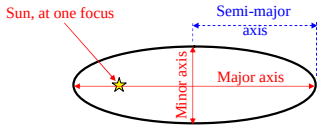
Brahe (1546-1601)

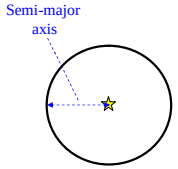
Kepler (1571-1630)

- Their meeting at Benatek (in Czechoslovakia)
  - …on 4 February 1600, Tycho de Brahe and Johannes Keplerus, co-founders of a new universe, met face to face, silver nose to scabby cheek. Tycho was fifty-three, Kepler, twenty-nine. Tycho was an aristocrat, Kepler a plebian. — Koestler, *The Sleepwalkers*, p302

Kepler's 3 Laws [Pg. 64]

- Each planet moves around orbit in ellipse, with sun at one focus.
- The straight line joining the planet and the sun sweeps out equal areas of space in equal amounts of time.
- $P^2 = a^3$
  - P = period of orbit, in years
  - a = semi-major axis of orbit, in au.

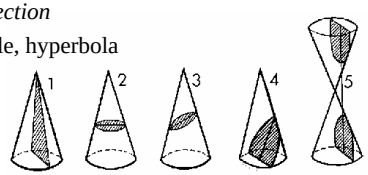




Earth's orbit is nearly circular

Kepler's first law:
Each planet moves around orbit in an ellipse, with the sun at one focus.

- Ellipse is a *conic section*
  - Along with circle, hyperbola



- This is an unexpected result…
  - Why an ellipse?
  - Why is sun at focus rather than at center??

Kepler1 simulation

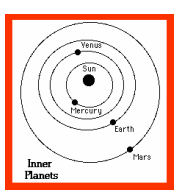
Kepler's second law:
The line joining the planet and the sun sweeps out equal areas of space in equal amounts of time.

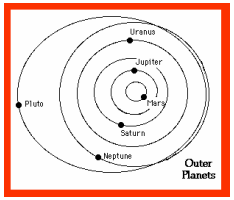
- planet moves more slowly when it is far from sun
- more rapidly when close to sun

- see the Kepler2 simulation

Kepler's third law: $P^2 = a^3$

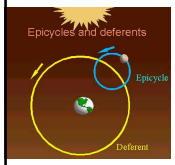
- P = period of orbit, in years
- a = semi-major axis of orbit, in au.

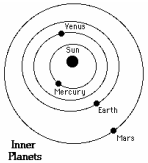




Fastsolar simulation

The Motions of the Planets





Ptolemy
140 AD

Copernicus
1543

Simpler model

Kepler
1609

More accurate description of data