

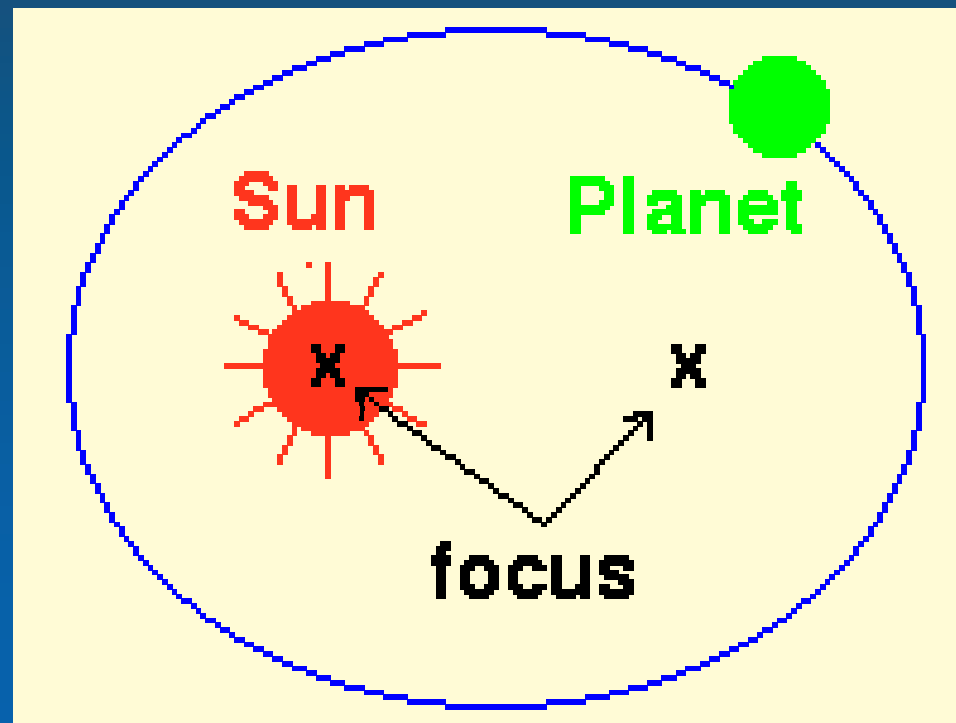
# Lecture 5: History of Cosmology III: Cosmology becomes a Science

# Just being smart is not enough ...

- Better data                      Tycho Brahe
- Final touch-up of  
the model                      Johannes Kepler
- Promotion of the  
new model                      Galileo Galilei

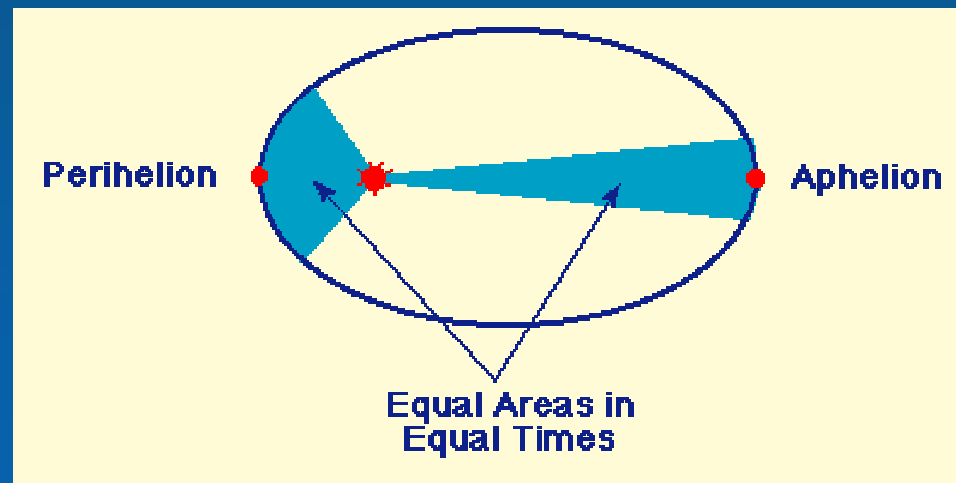
# Kepler's three laws of planetary orbits

**Kepler's first law:** Planets orbit the Sun in an ellipse, with the Sun at one focus.



# Kepler's three laws of planetary orbits

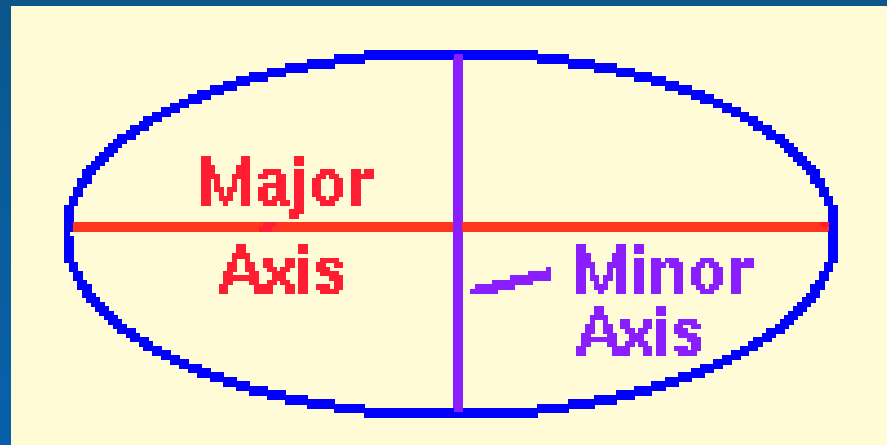
**Kepler's second law:** The line from the Sun to the planet sweeps out an equal area in an equal time. Thus planets move faster if they are nearer the Sun.



# Kepler's three laws of planetary orbits

**Kepler's third law:** The square of the period of the orbit is equal to the cube of the semimajor axis of the ellipse.

$$\frac{P_1^2}{P_2^2} = \frac{R_1^3}{R_2^3}$$



# What does Kepler III mean

- Example:
  - Earth distance to the Sun:  $R_E = 1$  AU
  - Orbital period:  $P_E = 1$  yr
  - Orbital period of Mars:  $P_M = 1.88$  yr  
⇒ Mars' distance to the Sun can be calculated:

$$\frac{R_M^3}{R_E^3} = \frac{P_M^2}{P_E^2} \Rightarrow R_M = 1.88^{2/3} \text{ AU} = 1.52 \text{ AU}$$

Still most important astronomical method to measure sizes of astronomical systems

# Another Example

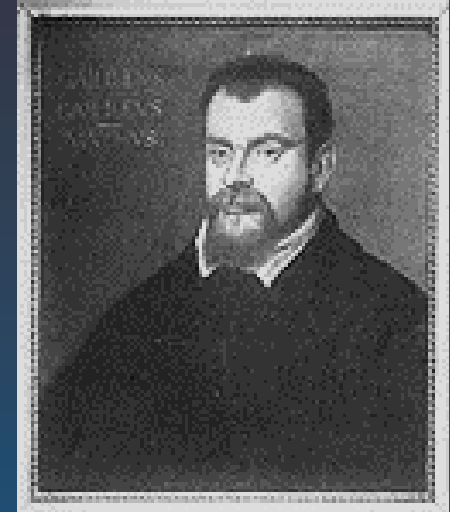
- 1781: Herschel discovered Uranus
  - Earth distance to the Sun:  $R_E = 1$  AU
  - Orbital period:  $P_E = 1$  yr
  - via parallax:  $R_U = 19.2$  AU

⇒ Uranus' orbital period can be calculated:

$$\frac{R_M^3}{R_E^3} = \frac{P_M^2}{P_E^2} \Rightarrow P_U = 19.2^{3/2} \text{ yr} = 84 \text{ yr}$$

# Galileo Galilei

## (1564-1642)



- Did not invented the telescope !
- Was the first to point the telescope at the night sky
- designed tests for Aristotle's physics and finally rejected it
- famous for his trial for heresy 1633
- exonerated in 1980 !

# Galileo's astronomical discoveries

- Mountains on the Moon similar to Earth  
⇒ not perfect spherical bodies
- Stars: point like, planets: spheres
- Phases of Venus ⚡ Ptolemaic world system
- Moons of Jupiter ⇒ miniature system
- Interpretation of Sun spots ⚡ unchanging heavens
- Milky Way = Zillions of Stars

# Galileo's physics

- concept of inertia and momentum:
  - Aristotle: force is responsible for motion
  - Galileo: force is responsible for **changes** in motion

⇒ relativity of uniform motion
- fall experiments: objects of different composition fall at the same rate ⚡ Aristotle  
⇒ basis for Einstein's equivalence principle
- thought experiments

# Galileo's trial

- Difficult, very arrogant personality
- he was reaching out to the public
- outstanding speaker and lecturer
- he published in Italian
- 1632 famous book *Dialogues Concerning Two Chief World Systems*: Aristotelian cosmology was defended by Simplicio, an obvious fool
- other, more extreme example: Giordano Bruno

- Better data

Tycho Brahe

- Final touch-up of the model

Johannes Kepler

- Promotion of the new model

Galileo Galilei

**Still missing:** someone to put the pieces together to form a coherent physical theory in the modern sense  $\Rightarrow$  **Sir Isaac Newton**