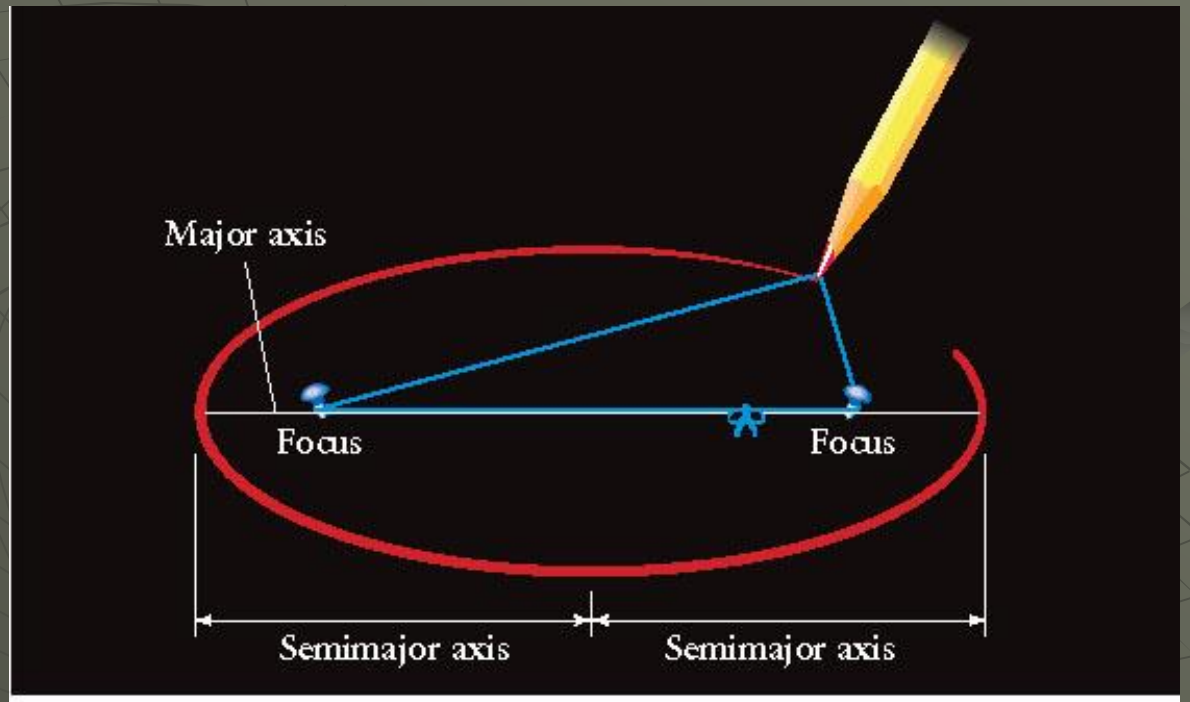
Orbits & Kepler's laws

- Objectives:
  - Kepler's laws (3)
  - Discover the path and speed of orbiting bodies at different positions in their orbits

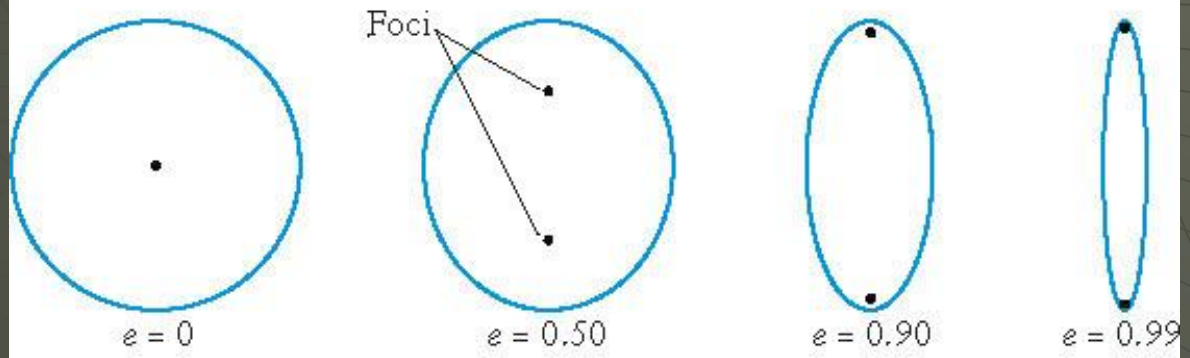
Kepler to the Rescue!

- Around the time Galileo was imprisoned…
- Tycho Brahe made really, really detailed observations of Mars over an extended period of time
  - Lost a part of his nose in a duel over who was the better mathematician…
- Johanes Kepler took these observations and came up with an unheard of idea: orbits are not circles!
  - They are ellipses.

Elliptical Orbits



(a) The geometry of an ellipse



(b) Ellipses with different eccentricities

Eccentricity (e): How "stretched" the ellipse is. For a circle, e=0; for a line, e=1

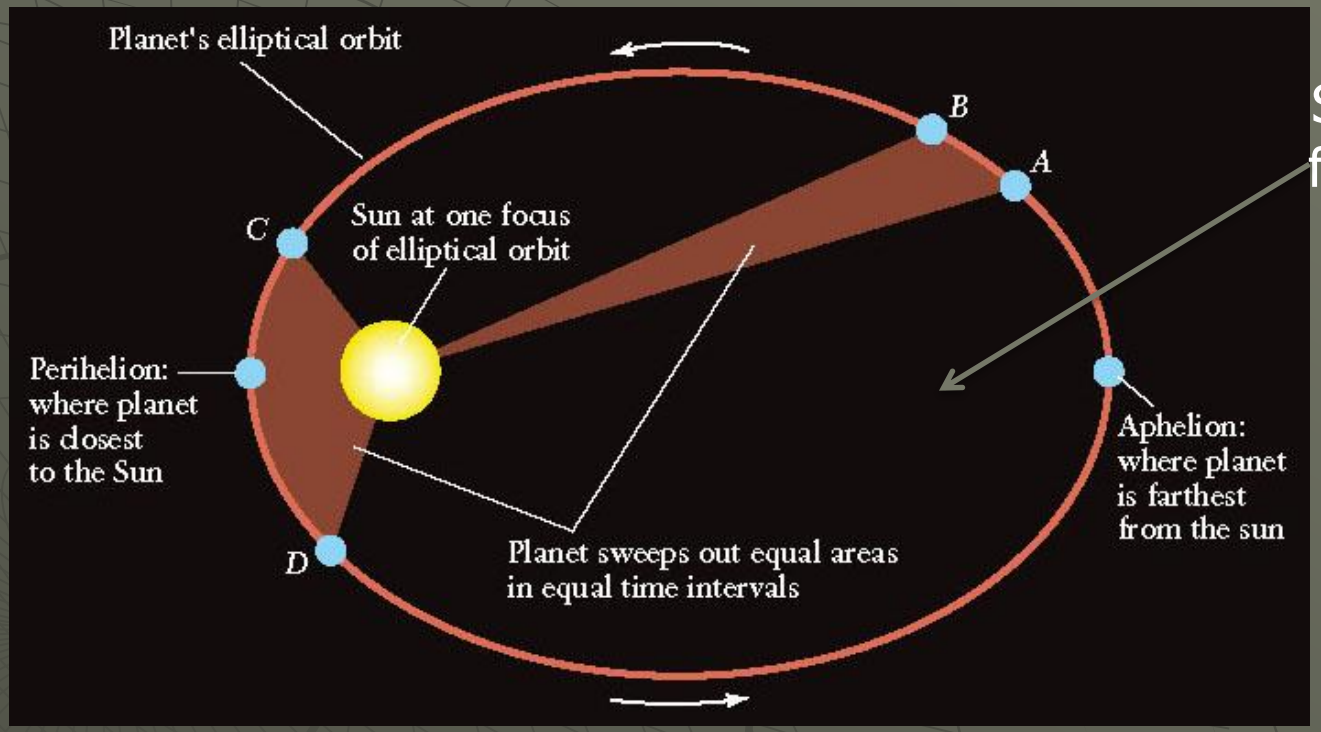
Focus (foci) : Points where tacks go. For a circle, the center is both foci on top of each other

Semimajor axis (a) : Half of the longest part of the ellipse. *Aka: average Sun-Planet distance.*

Kepler's 1st Law

1. The orbit of a planet about the Sun is an ellipse with the Sun at one focus

Greatly Exaggerated!



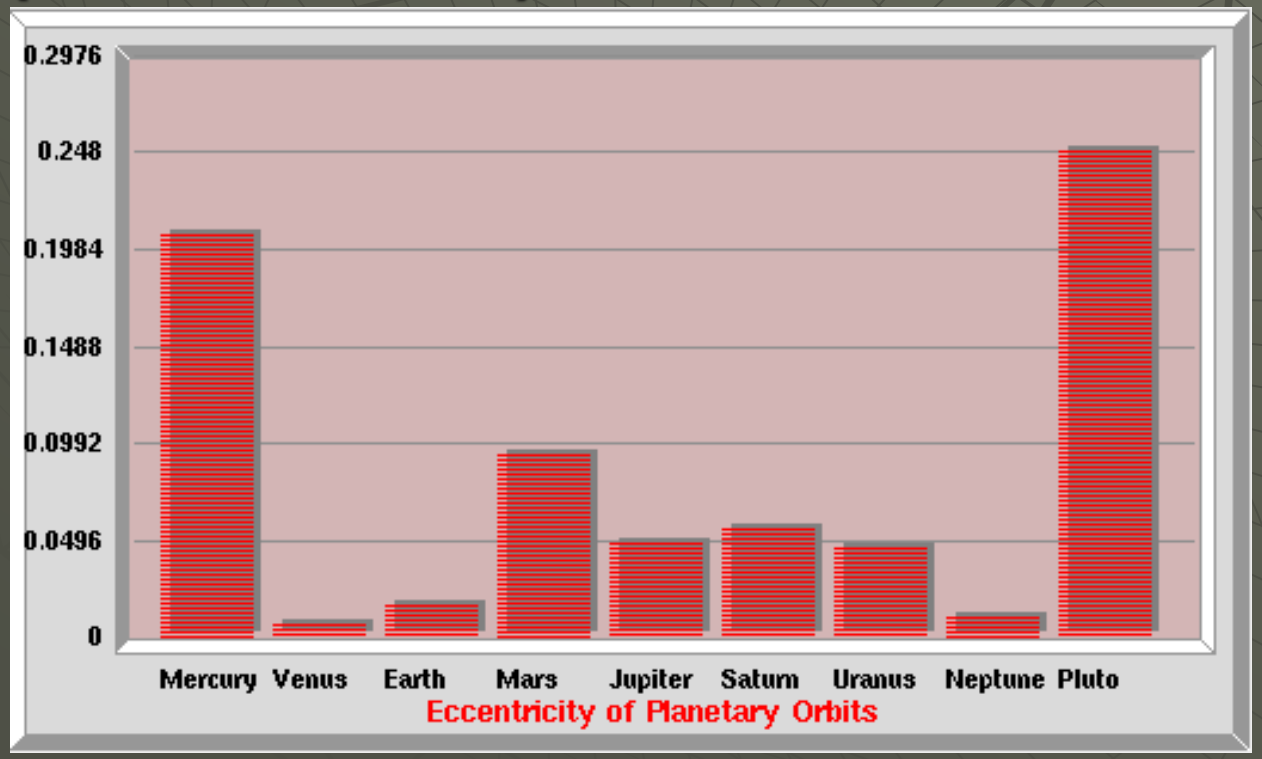
Second focus is empty

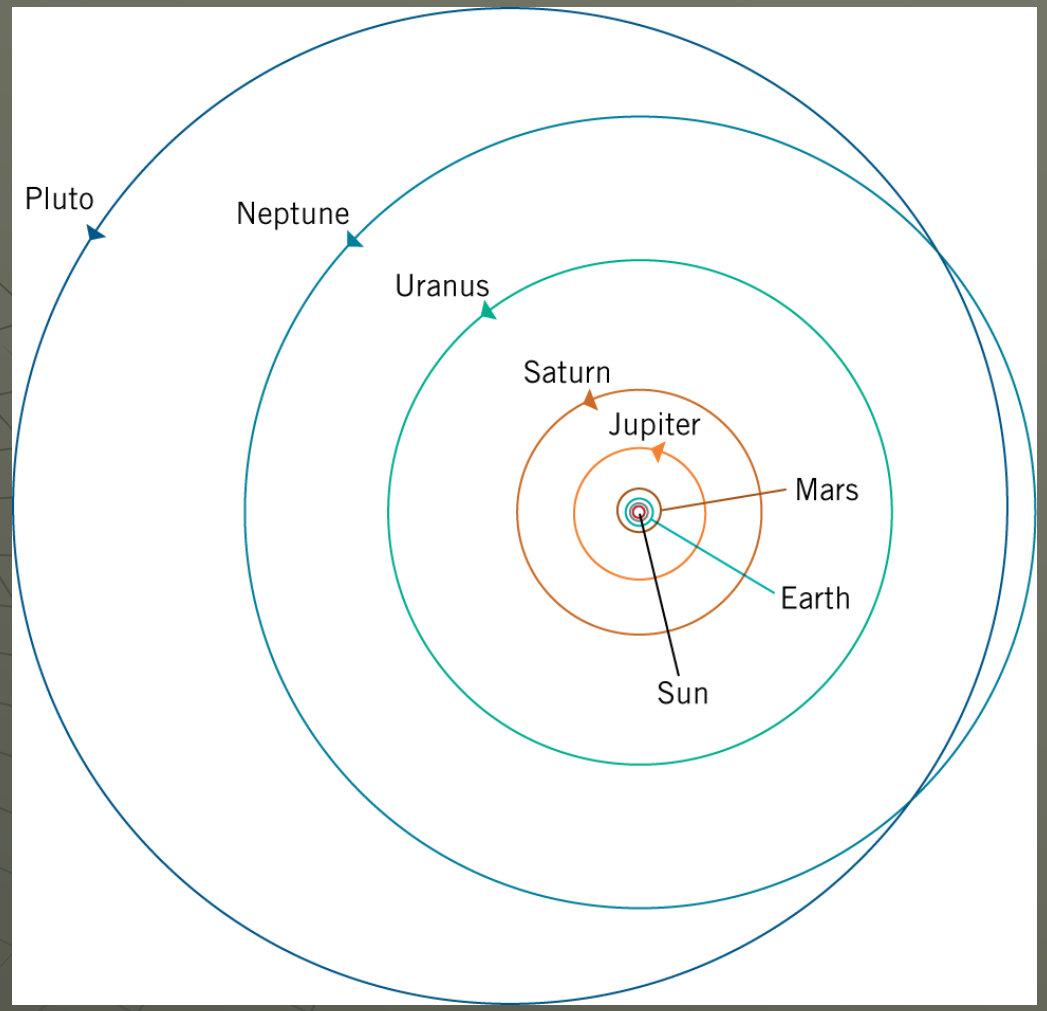
Perihelion = closest point to Sun

Aphelion = farthest point from Sun

Real Orbits

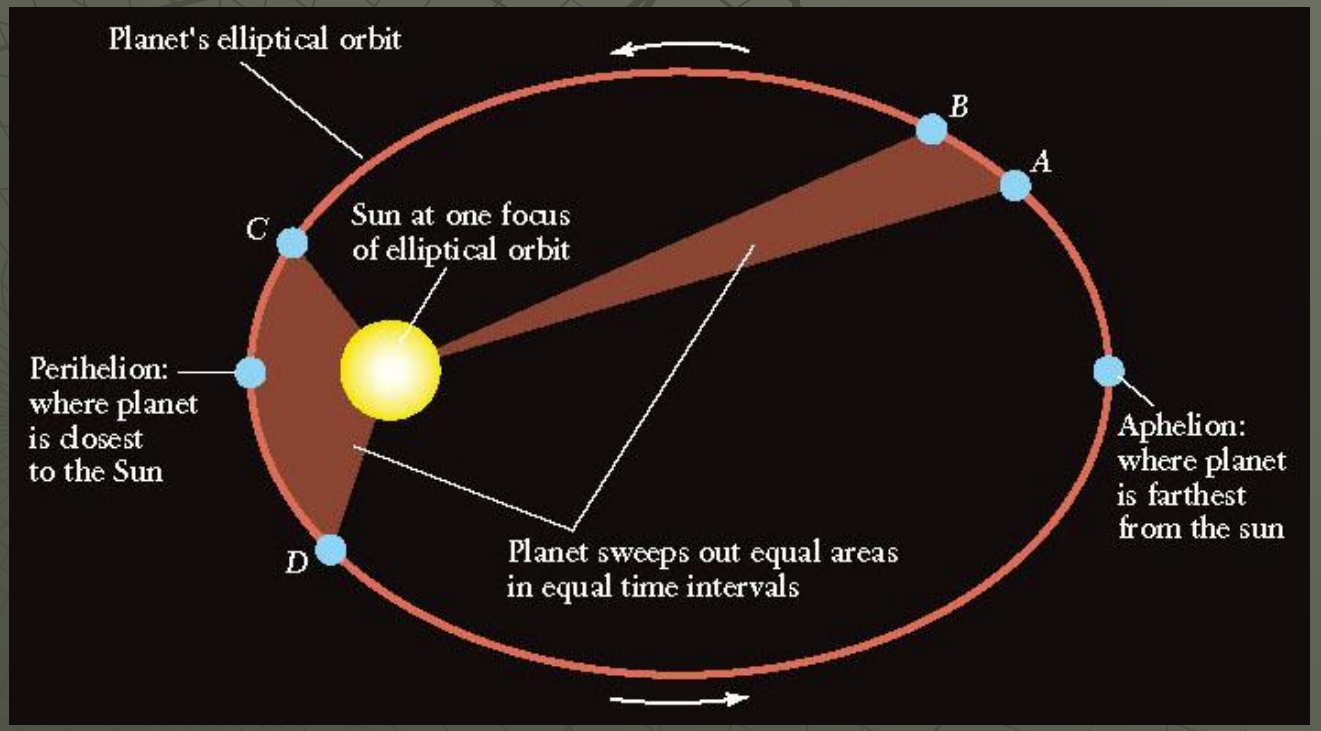
- Most Planets eccentricity is near 0
- **Astronomical Unit (AU) =** Average Sun-Earth distance (1.5×10^8 km)





Kepler's Laws

2. A line joining a planet and the Sun sweeps out equal areas in equal intervals of time (law of equal areas)



Animation

tps

- Q: Mercury's orbit is more elliptical than Earth's, but closer to the Sun. Which planet has a greater variation in orbital speed?

A. Earth, because it has a larger orbit.
B. Mercury, because its orbit is more elliptical.
C. Both planets have the same variation in orbital speed.
D. Both planets orbit at a constant speed.

- Q: If a comet has a highly elliptical orbit around the Sun, where does it spend most of its orbit?

A. Close to the Sun
B. Far from the Sun
C. Moving toward the Sun
D. Moving away from the Sun

LT

- Kepler’s second law
  - pg

Kepler's Laws

3. The square of the sidereal period of a planet is directly proportional to the cube of the semimajor axis of the orbit

Mathematically:

$$P^2=a^3$$

In our solar system: (anything going around the Sun)

- the period P *MUST* be in years
- the semimajor axis a *MUST* be in AUs

Kepler's Laws

- Kepler's Laws hold for any orbiting bodies (satellites, binary stars...), not just the planets

- They allowed more accurate predictions than the geocentric model, and it was simpler! Thus the heliocentric model was finally becoming widely accepted

- Still questions though: just because the model fits, still no answer to why? Why do the planets orbit the Sun in this way?

tps

Q:A fictional planet lies twice as far away from the Sun than Earth (at a distance of 2 AU). How long is its period of orbit?

A. Less than half of one year
B. Exactly half of one year
C. Exactly two years
D. More than two years

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- Kepler’s third law
  - pg