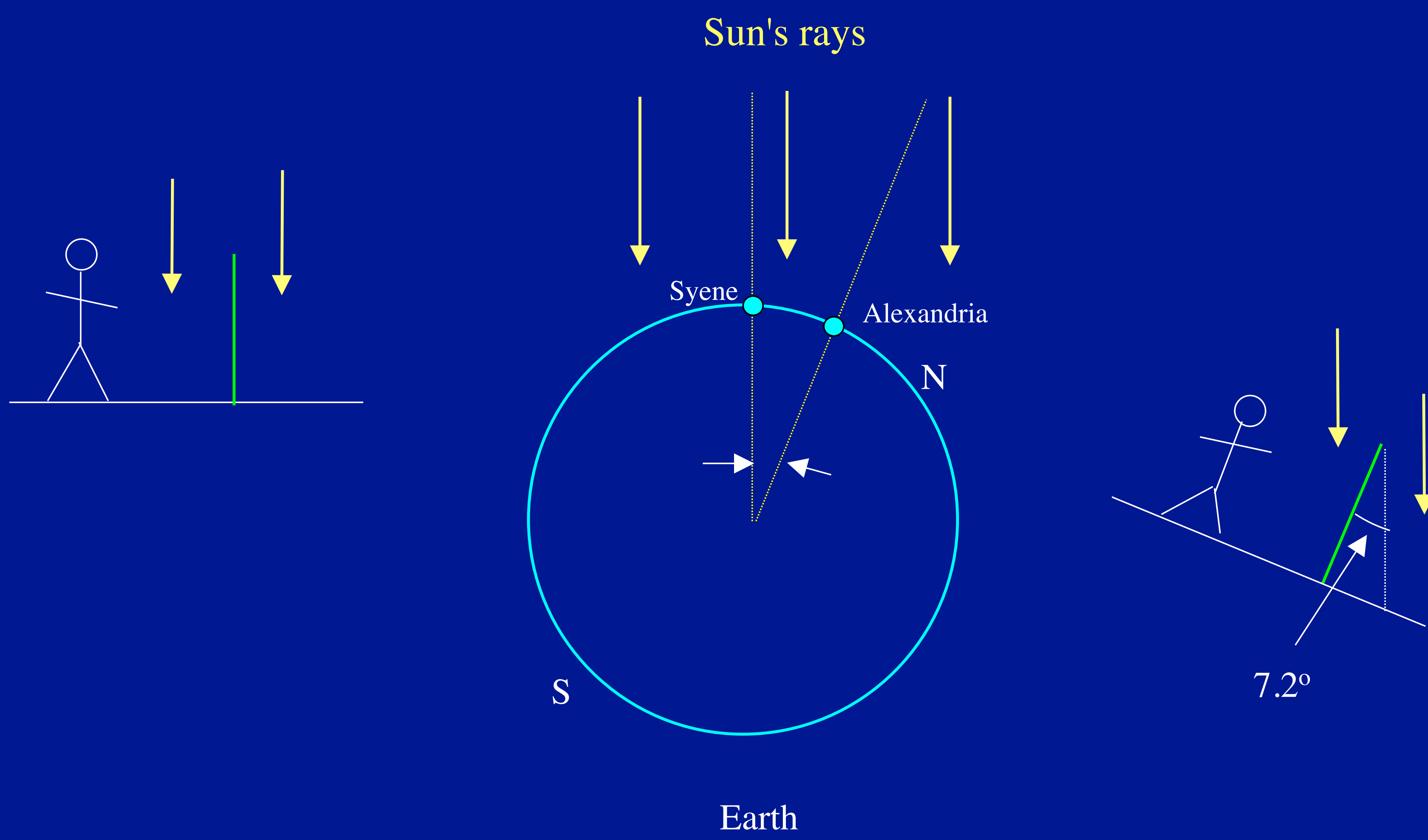
Announcements

- First Homework is Due today
- Homework grading will become stricter on HW#2
- TA (Chris DiLullo) will be in RH111 4:30-5:30pm
Chris' e-mail is cdilullo@unm.edu
- Sept 9 is the last day to drop without late fee
- If your clicker is not registered <u>and</u> you are not set up in SmartWorks by Sept 8 you will be dropped from this course

Eratosthenes Determines the Size of the Earth in about 200 B.C.



He knows the distance between the two cities is 5000 "stadia".

From geometry then,

$$\frac{7.2^{o}}{360^{o}} = \frac{5000 \text{ stadia}}{\text{Earth's circumference}}$$

=> circumference is 250,000 stadia, or 40,000 km.

So radius is:

$$\frac{40{,}000 \text{ km}}{2\pi} = 6366 \text{ km}$$

(very close to modern value, 6378 km!)

From Aristotle to Newton

The history of our knowledge about the Solar System (and the universe to some extent) from ancient Greek times through to the beginnings of modern physics.

Clicker Review:

What time of day does the first quarter moon set?

A: 6am

B: noon

C: 6pm

D: midnight

E: Never sets

Clicker Question:

Who was the first person to use a telescope to make astronomical discoveries?

A: Aristotle

B: Brahe

C: Kepler

D: Gallileo

E: Newton

"Geocentric Model" of the Solar System

Ancient Greek astronomers knew of Sun, Moon, Mercury, Venus, Mars, Jupiter and Saturn.

Aristotle vs. Aristarchus (3rd century B.C.)

Aristotle: Sun, Moon, Planets and Stars rotate around fixed Earth.

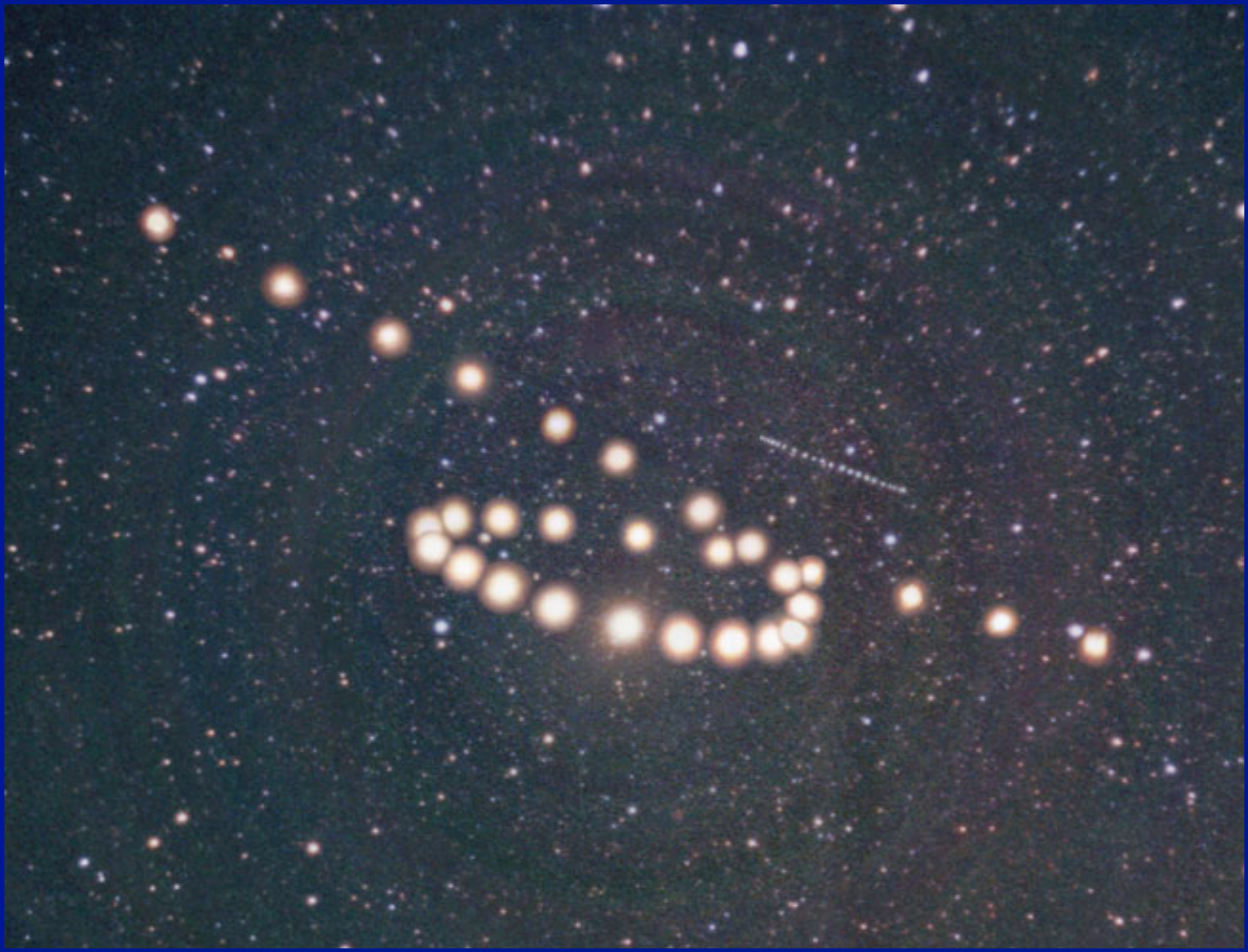
Aristarchus: Used geometry of eclipses to show Sun bigger than Earth (and Moon smaller), so guessed that Earth orbits the Sun. Also guessed Earth spins on its axis once a day => apparent motion of stars.

Aristotle: But there's no wind or parallax.

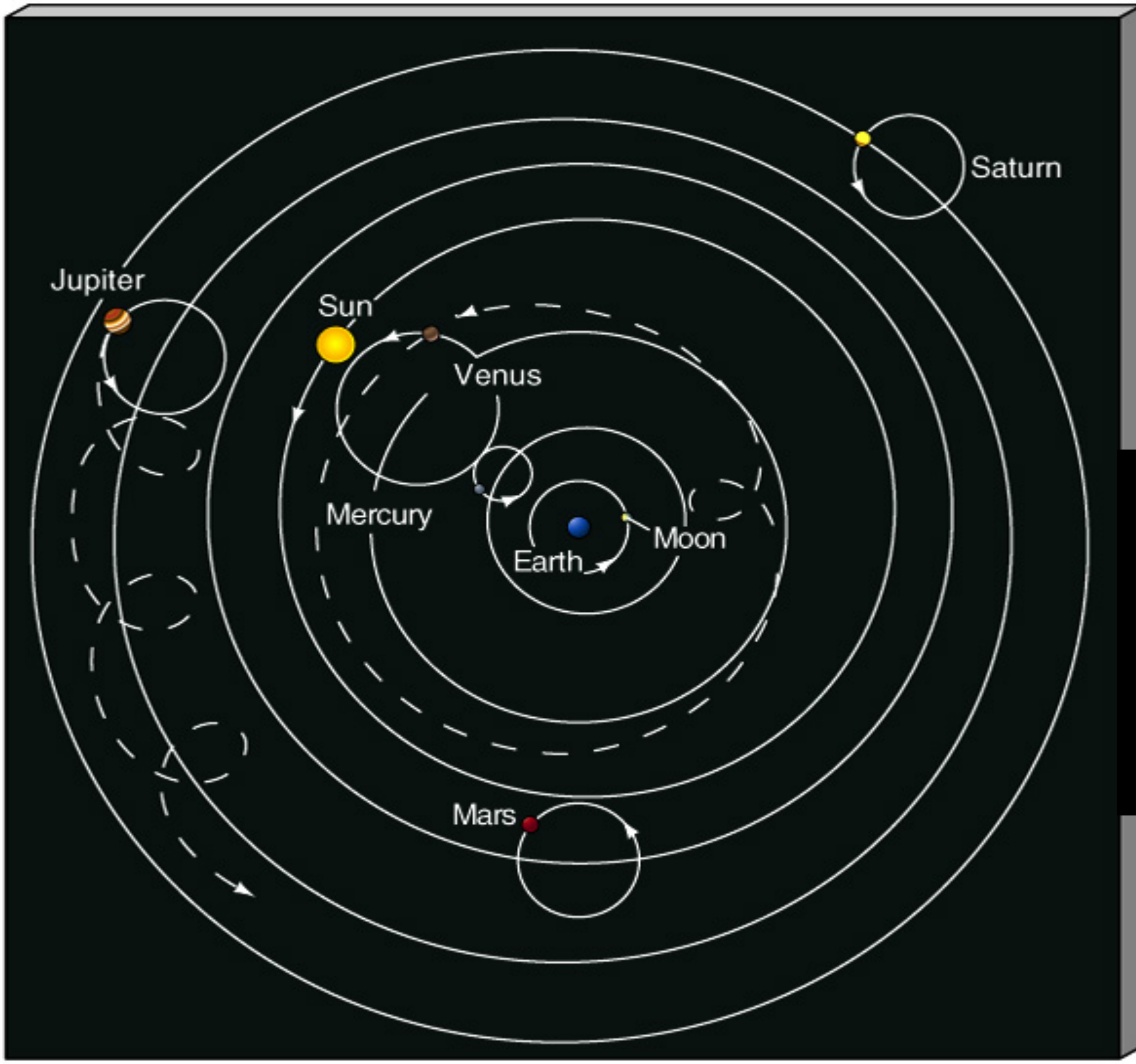
Aristarchus: Yes, sir

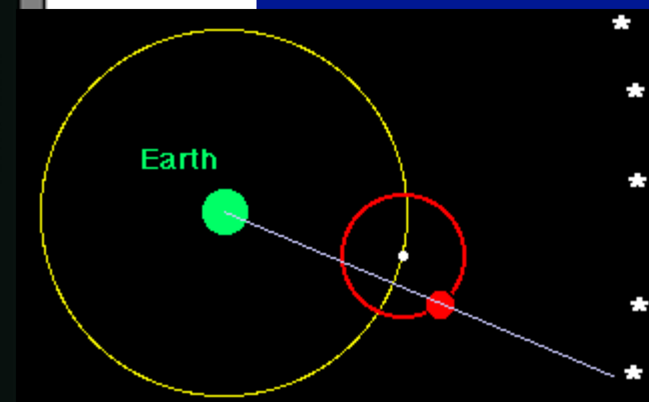
Difficulty with Aristotle's "Geocentric" model: "Retrograde motion of the planets".

Planets generally move in one direction relative to the stars, but sometimes they appear to loop back. This is "retrograde motion".



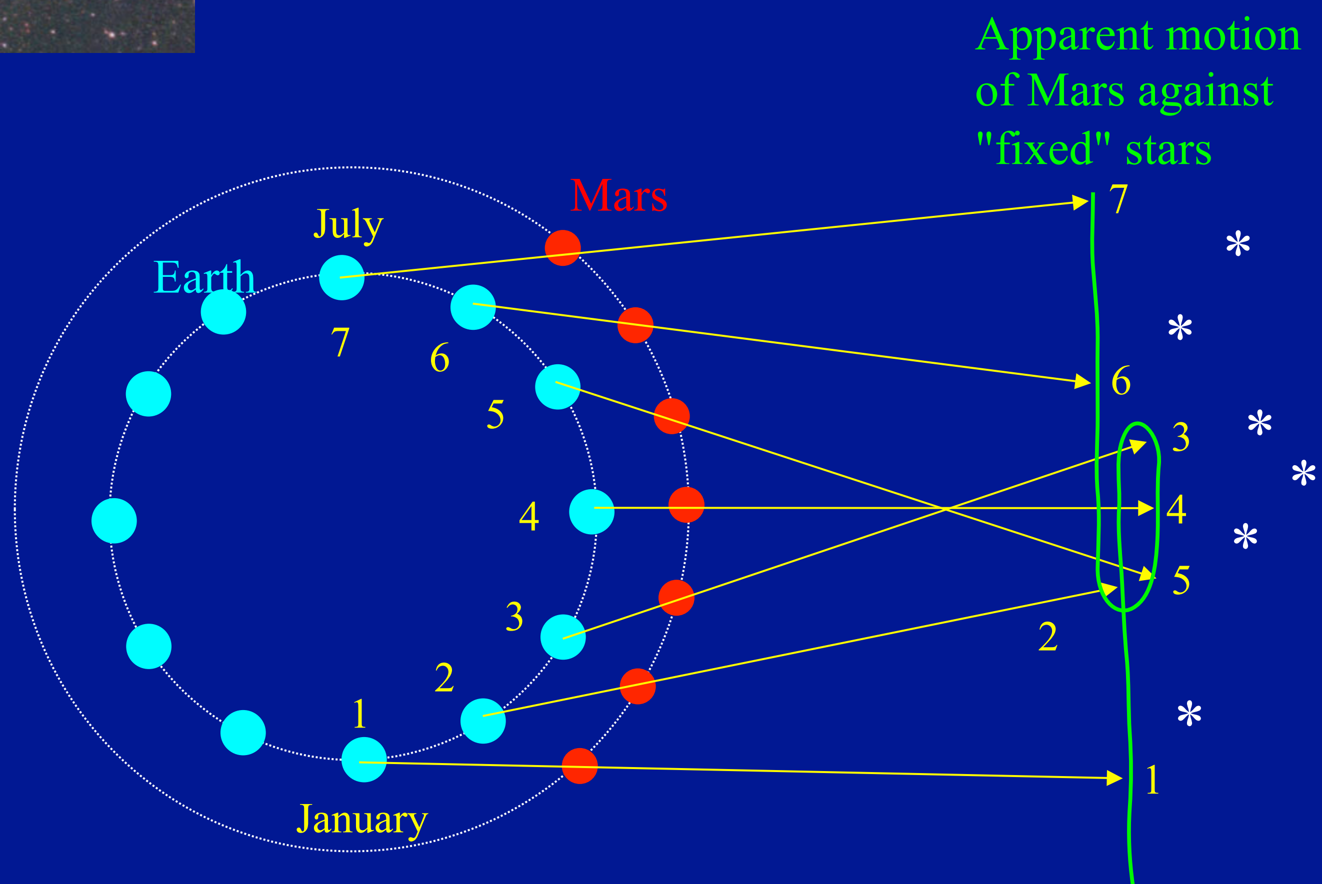
But if you support geocentric model, you must attribute retrograde motion to actual motions of planets, leading to loops called "epicycles".





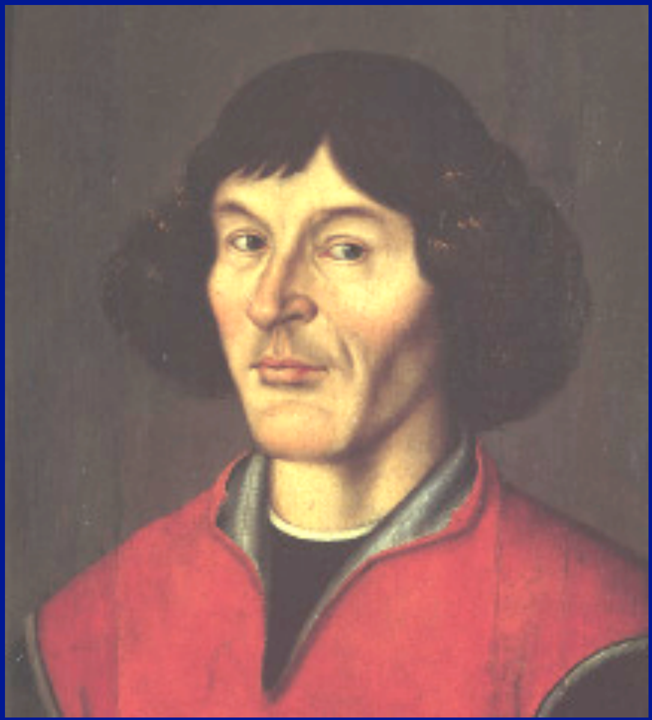
Ptolemy's geocentric model (A.D. 140)

Planets generally move in one direction relative to the stars, but sometimes they appear to loop back. This is "retrograde motion".



"Heliocentric" Model

- Rediscovered by Copernicus in 16th century.
- Put Sun at the center of everything.
- Much simpler. Almost got rid of epicycles.
- But orbits circular in his model. In reality, they're elliptical, so it didn't fit the data well.
- Not generally accepted at the time.



Copernicus 1473-1543

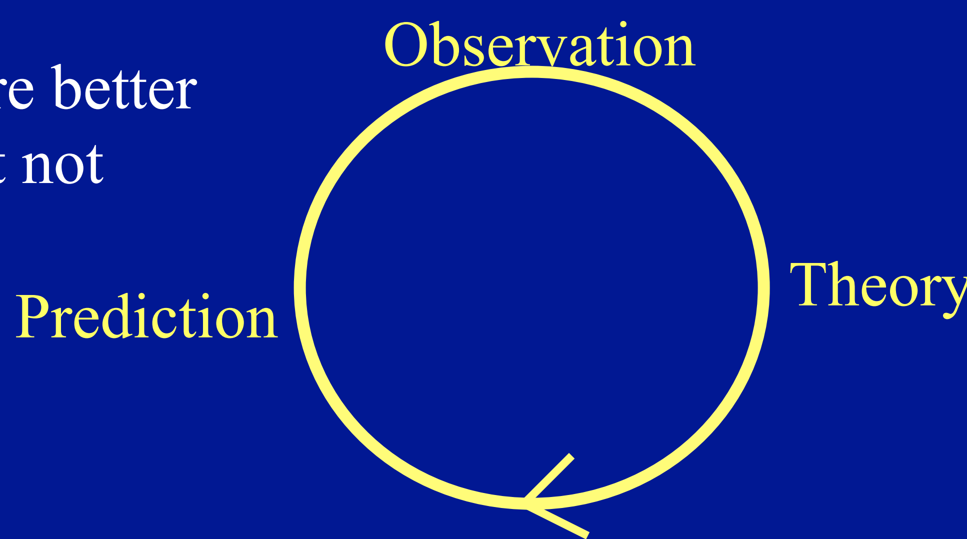
Illustration from Copernicus' work showing heliocentric model.

Copernican model was a triumph of the Scientific Method

Scientific Method:

a) Make high quality observations of some natural phenomenon
b) Come up with a theory that explains the observations
c) Use the theory to predict future behavior
d) Make further observations to test the theory
e) Refine the theory, or if it no longer works, make a new one

- Occam's Razor: Simpler Theories are better
- You can prove a theory WRONG but not RIGHT



Galileo (1564-1642)

Built his own telescope.

Discovered four moons orbiting Jupiter => Earth is not center of all things!

Discovered sunspots. Deduced Sun rotated on its axis.

Discovered phases of Venus, inconsistent with geocentric model.

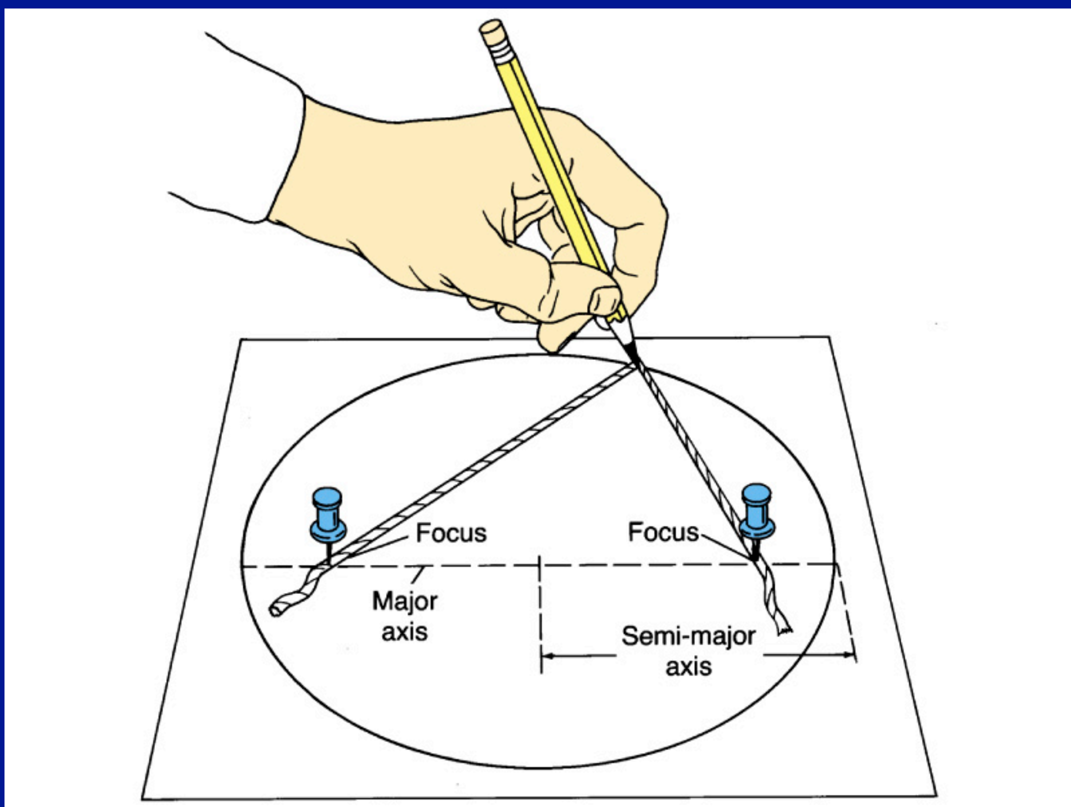
Kepler (1571-1630)

Used Tycho Brahe's precise data on apparent planet motions and relative distances.

Deduced three laws of planetary motion.

Kepler's First Law

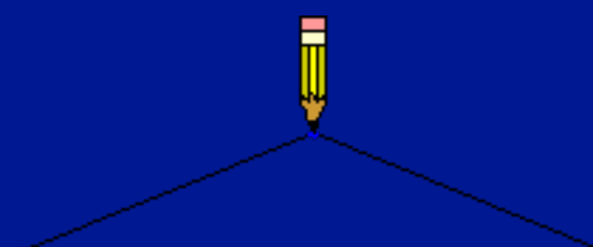
The orbits of the planets are elliptical (not circular) with the Sun at one focus of the ellipse.



Ellipses

$$\text{eccentricity} = \frac{\text{distance between foci}}{\text{major axis length}}$$

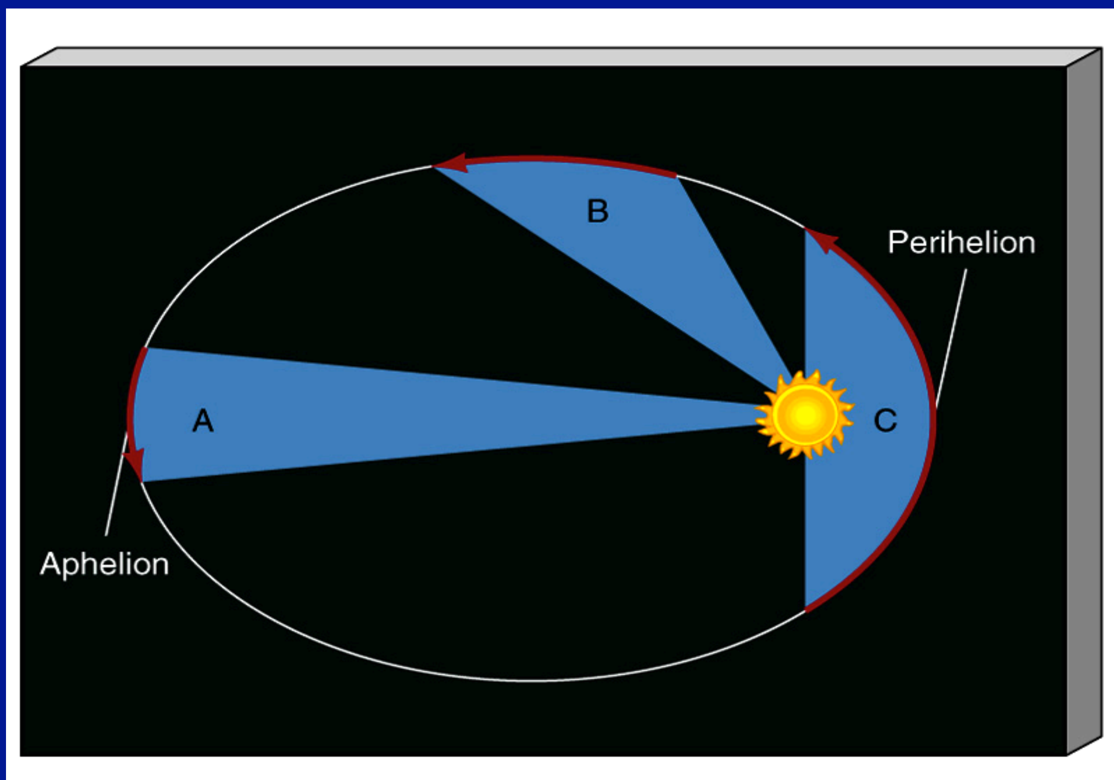
(flatness of ellipse)



Kepler's Second Law

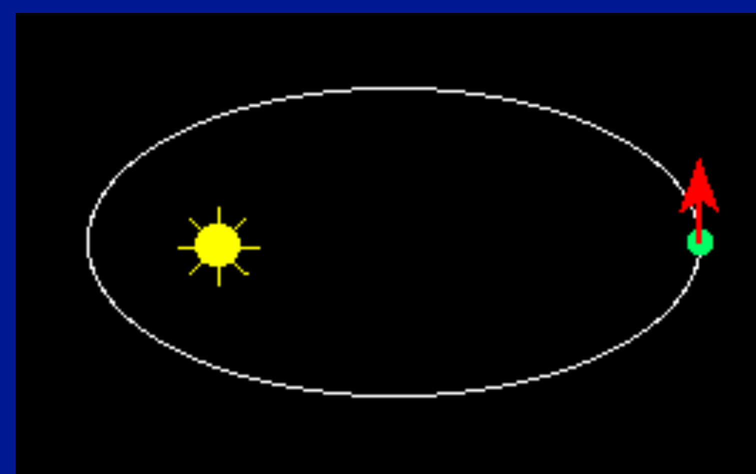
A line connecting the Sun and a planet sweeps out equal areas in equal times.

slower



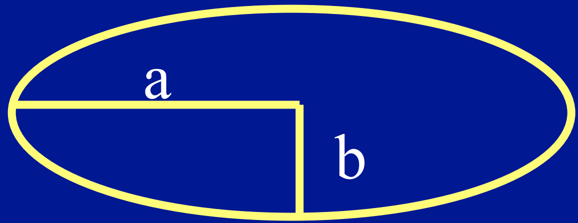
faster

Translation: planets move faster when closer to the Sun.



Kepler's Third Law

The square of a planet's orbital period is proportional to the cube of its semi-major axis.



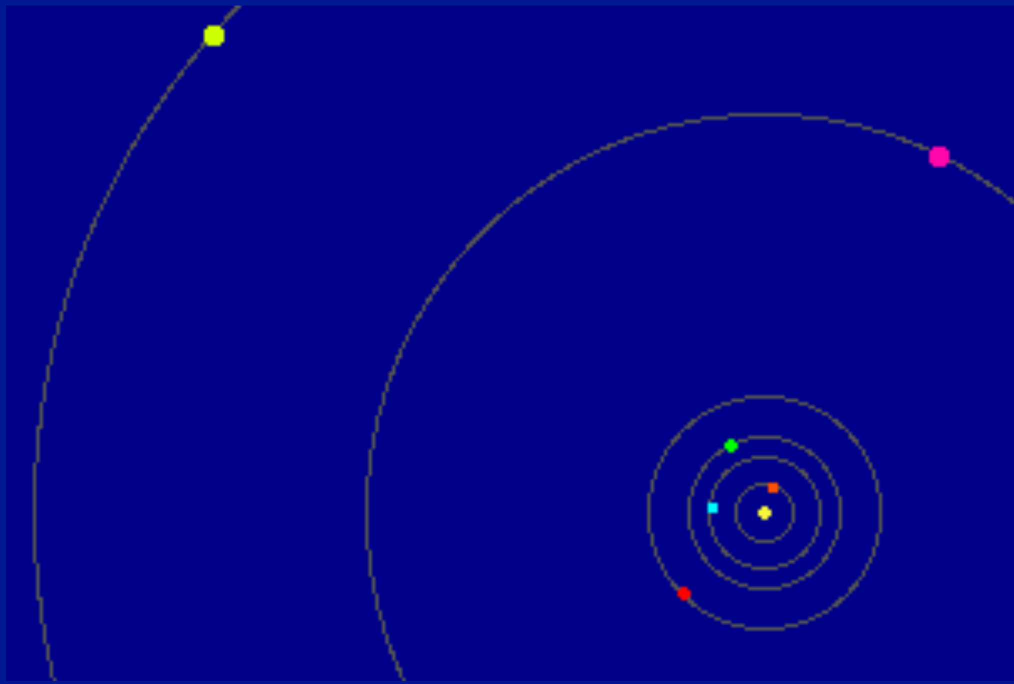
P^2 is proportional to a^3

or

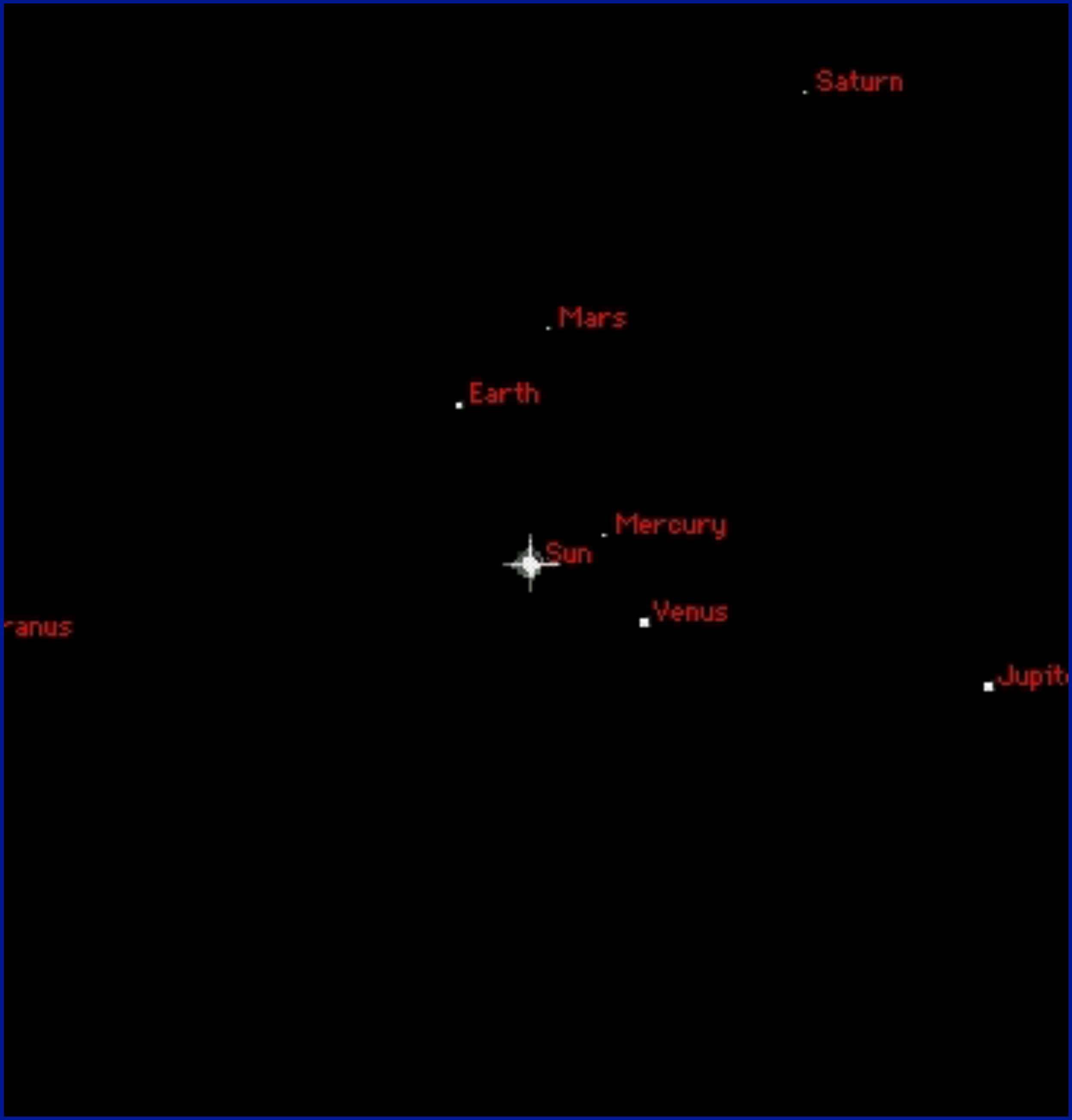
$$P^2 \alpha a^3$$

(for circular orbits, a=b=radius).

Translation: the larger a planet's orbit, the longer the period.



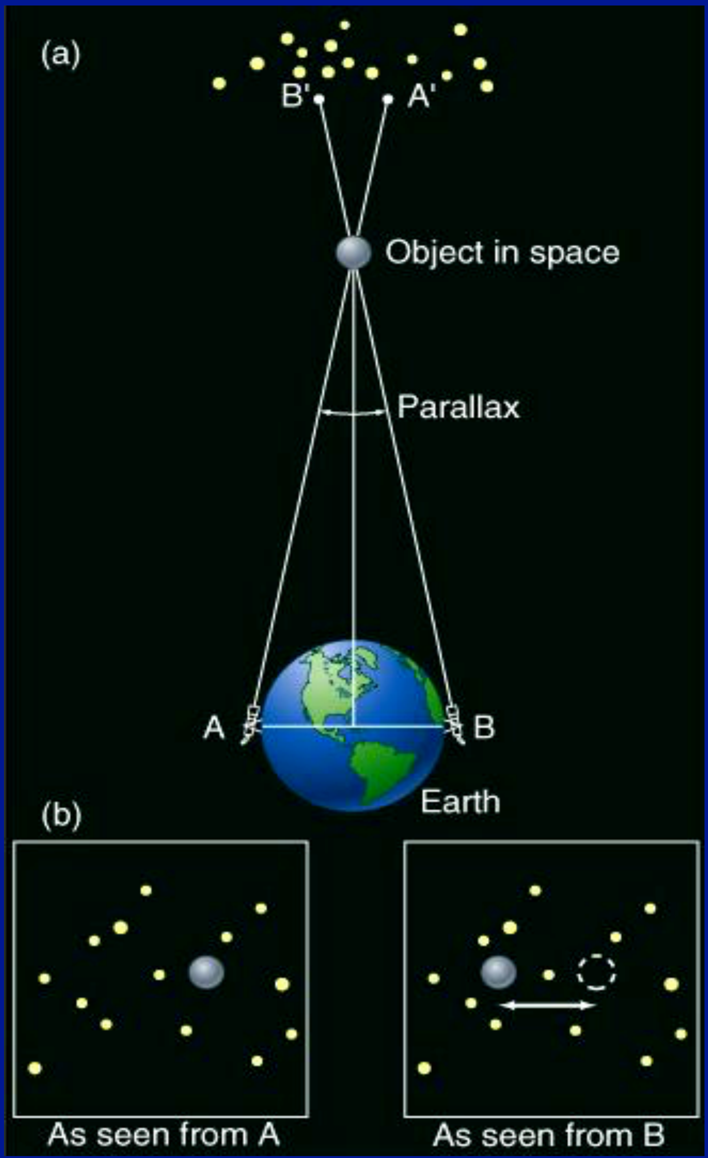
Solar System Orbits



Orbits of some planets (or dwarf planets):

Planet	a (AU)	P (Earth years)
Venus	0.723	0.615
Earth	1.0	1.0
Jupiter	5.2	12
Pluto	39.5	249

At this time, actual distances of planets from Sun were unknown, but were later measured. One technique is "parallax"



"Earth-baseline parallax" uses telescopes on either side of Earth to measure planet distances.

Clicker Question:

A flaw in Copernicus's model for the solar system was:

A: It didn't explain retrograde motion.

B: He used circular orbits.

C: The Earth was still at the center.

D: He used the same mass for all the planets.

E: All of the above

Clicker Question:

An asteroid orbiting the sun at a distance in between Earth and Mars will be moving:

A: Faster than the Earth but slower than Mars

B: Faster than Mars but slower than the Earth

C: Faster or Slower than Earth depending on its mass

D: At the same speed as the asteroid belt

Newton (1642-1727)

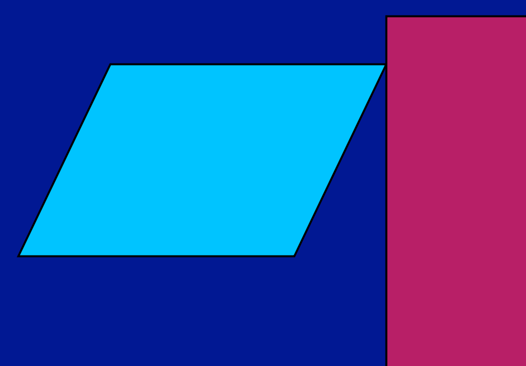
Kepler's laws were basically playing with mathematical shapes and equations and seeing what worked.

Newton's work based on experiments of how objects interact.

His three laws of motion and law of gravity described how <u>all</u> objects interact with each other.

Newton's First Law of Motion

Every object continues in a state of rest or a state of uniform motion in a straight line unless acted on by a force.



Newton's First Law of Motion

DEMO - Smash the HAND

Newton's Second Law of Motion

When a force, F, acts on an object with a mass, m, it produces an acceleration, a, equal to the force divided by the mass.

$$a = \frac{F}{m}$$

or $F = ma$

acceleration is a change in velocity or a change in direction of velocity.

Demo - Measuring Force and Acceleration

Newton's Third Law of Motion

To every action there is an equal and opposite reaction.

Or, when one object exerts a force on a second object, the second exerts an equal and opposite force on first.

Newton's Third Law of Motion

DEMO: CART

Newton's Law of Gravity

For two objects of mass m_1 and m_2, separated by a distance R, the force of their gravitational attraction is given by:

$$F = \frac{G\, m_1\, m_2}{R^2}$$

F is the gravitational force.

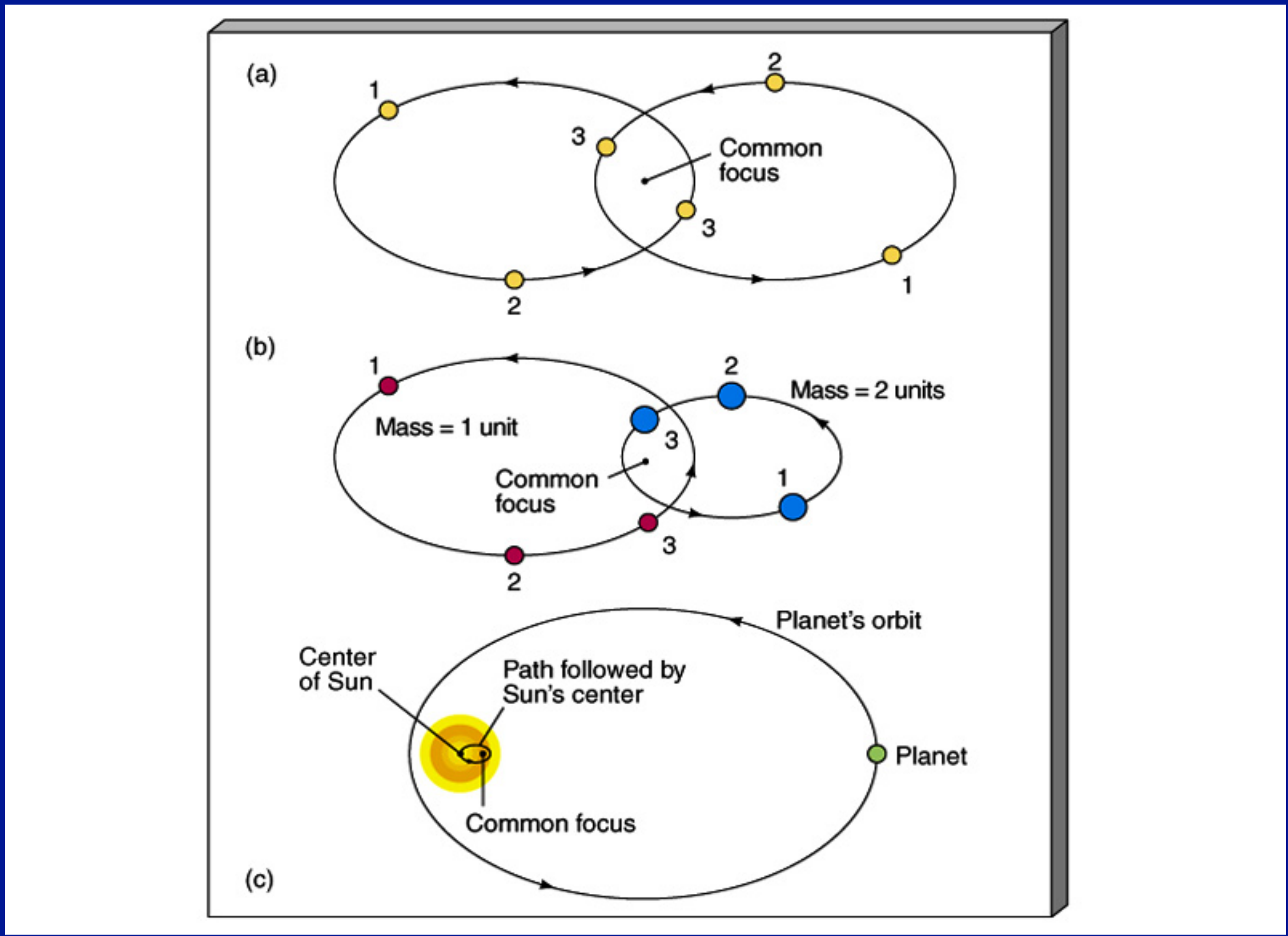
G is the "gravitational constant".

An example of an "inverse-square law".

Your "weight" is just the gravitational force between the Earth and you.

Newton's Correction to Kepler's First Law

The orbit of a planet around the Sun has the common center of mass (instead of the Sun) at one focus.



Clicker Question:

Why didn't my hand get crushed by the hammer?

A: My bones are actually stronger than steel.

B: The plate has a lot of inertia

C: The plate is very strong

D: The force of gravity kept the plate from moving

Clicker Question:

Suppose Matt weighs 120 lbs on his bathroom scale on Earth, how much will his scale read if he standing on a platform 6400 km high (1 Earth radius above sea-level)?

A: 12 lbs

B: 30 lbs

C: 60 lbs

D: 120 lbs

E: 240 lbs

Escape Velocity

Velocity needed to completely escape the gravity of a planet.
The stronger the gravity, the higher the escape velocity.
Examples:

Earth	11.2 km/s
Jupiter	60 km/s
Deimos (moon of Mars)	7 m/s = 15 miles/hour

Consider Helium Gas at room temperature (300 K)

$E = kT = 4.1 \times 10^{-14}$ erg

$E = 0.5\ m\ v^2 = 4.1 \times 10^{-14}$ erg

so $v = 1$ km/sec on average, but sometimes more

Timelines of the Big Names

Galileo

1564-1642

Copernicus

1473-1543

Brahe

1546-1601

Newton

1642-1727

Kepler

1571-1630