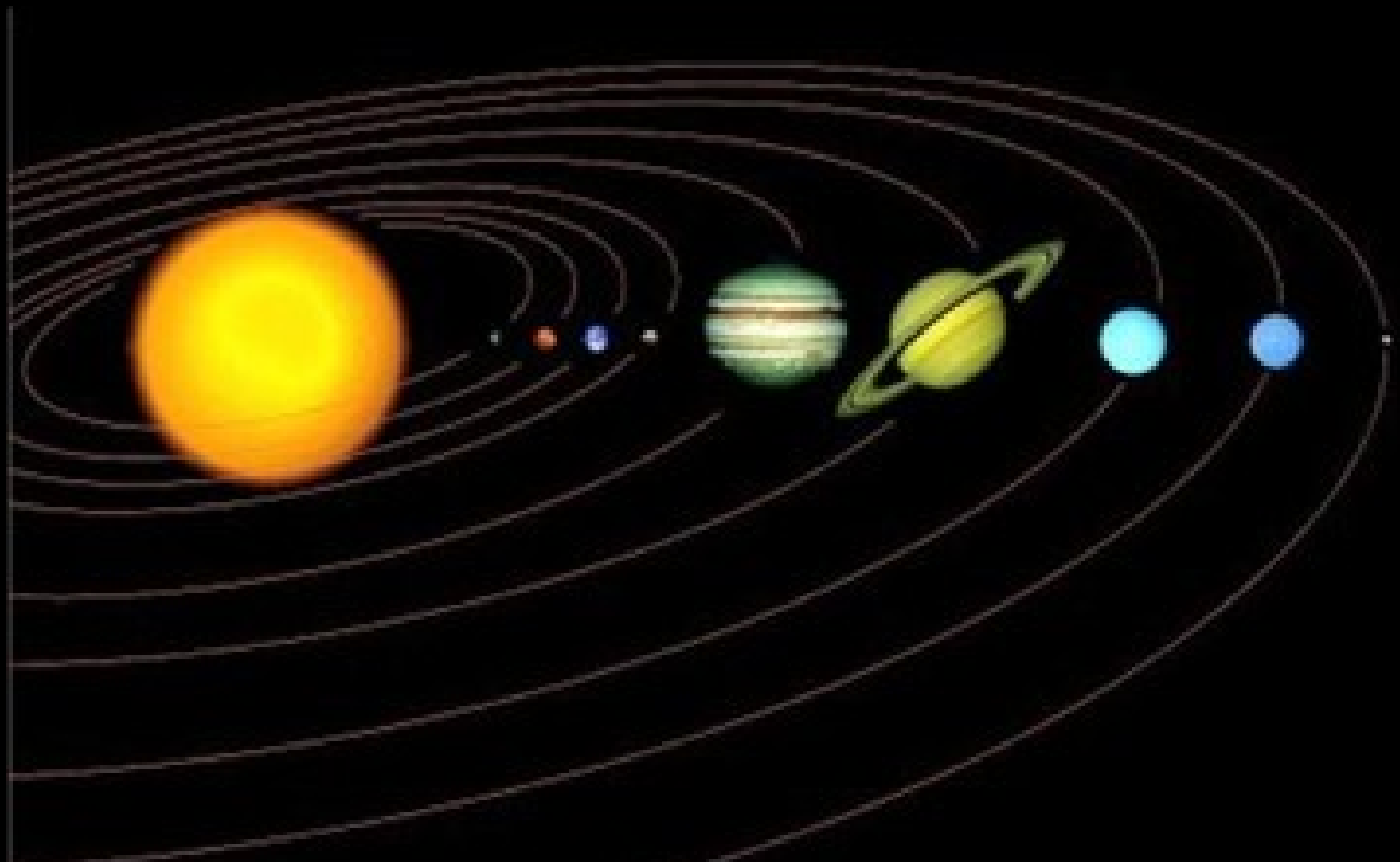
Orbits of the planets



If the tilt of the Earth's axis were zero degrees instead of 23.5 degrees then

A) There would be no seasons

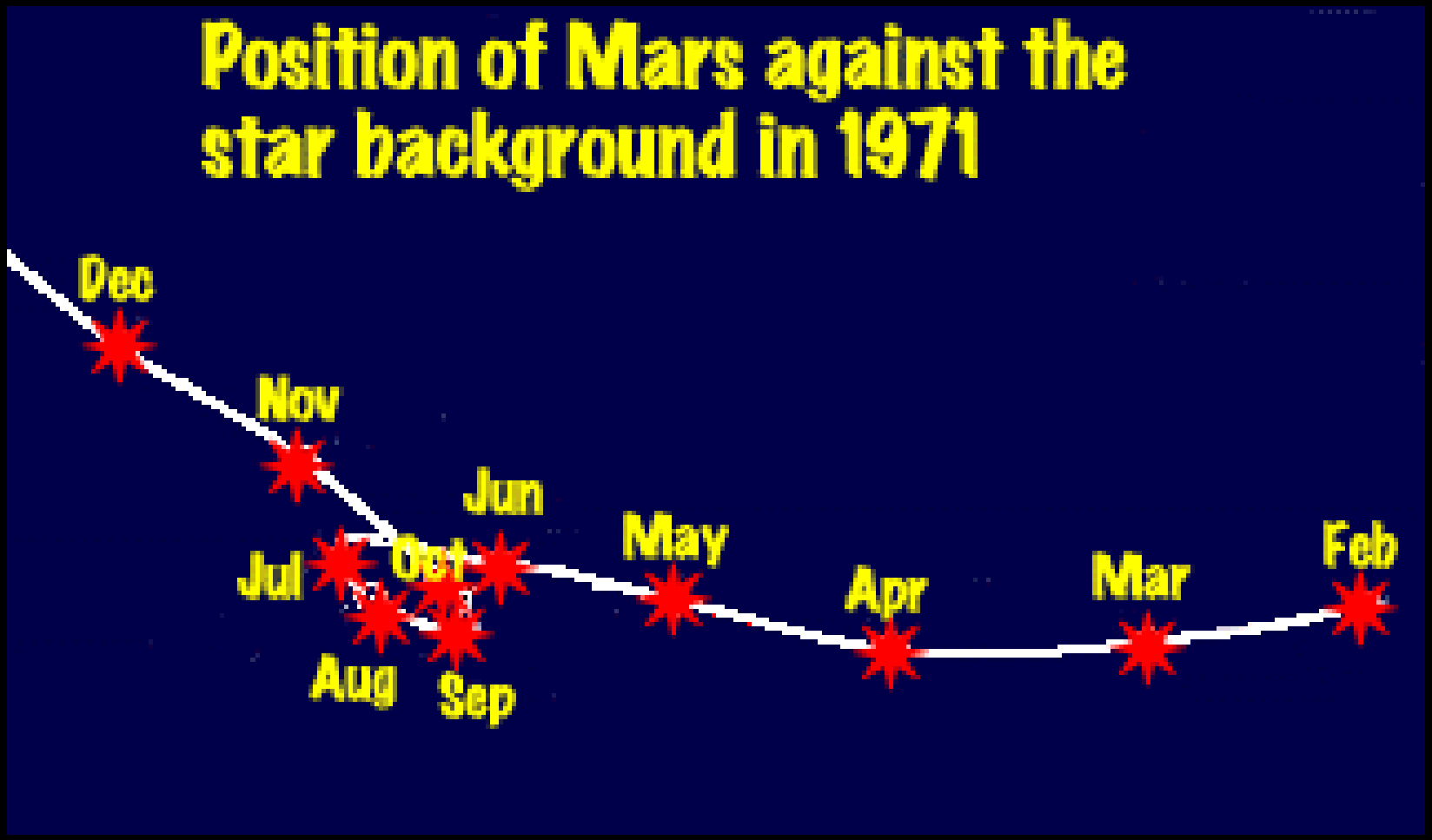
B) The Sun would always rise due east and set due west

C) The celestial equator and the ecliptic would be the same

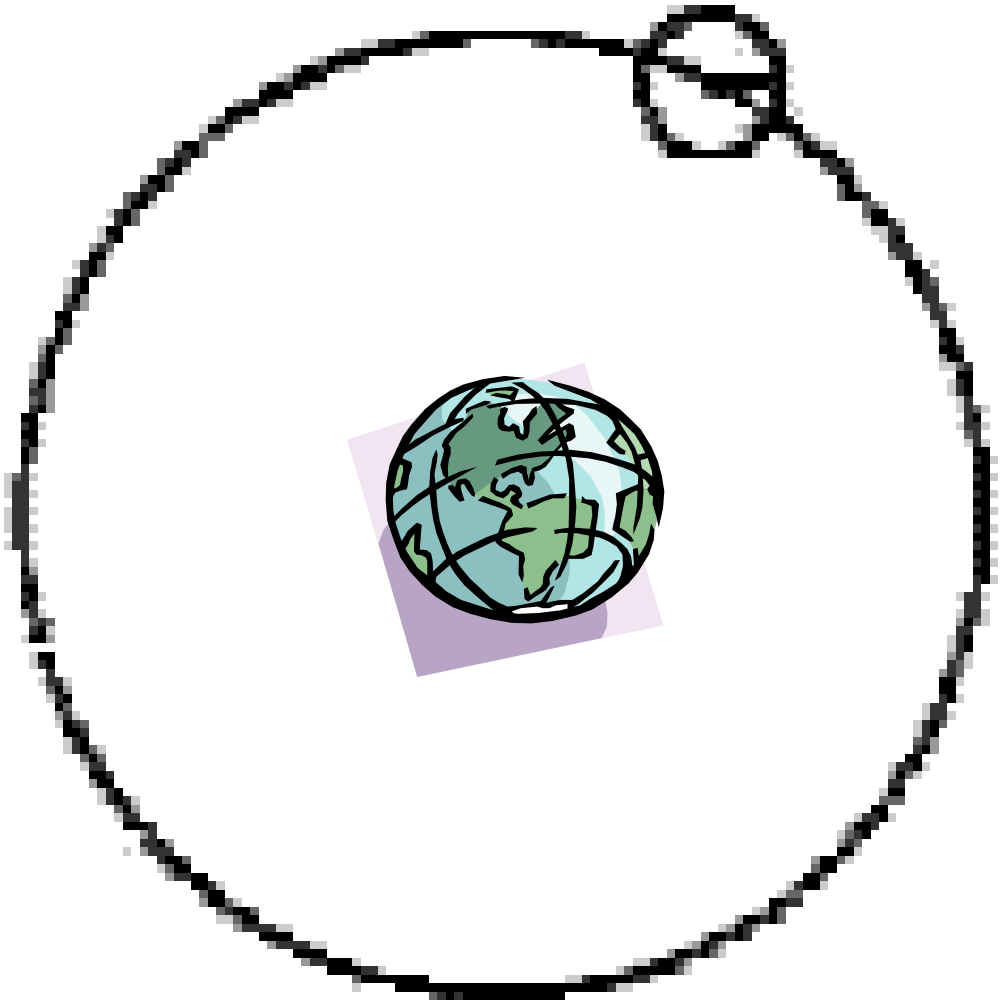
D) All of the above are true

E) No clue

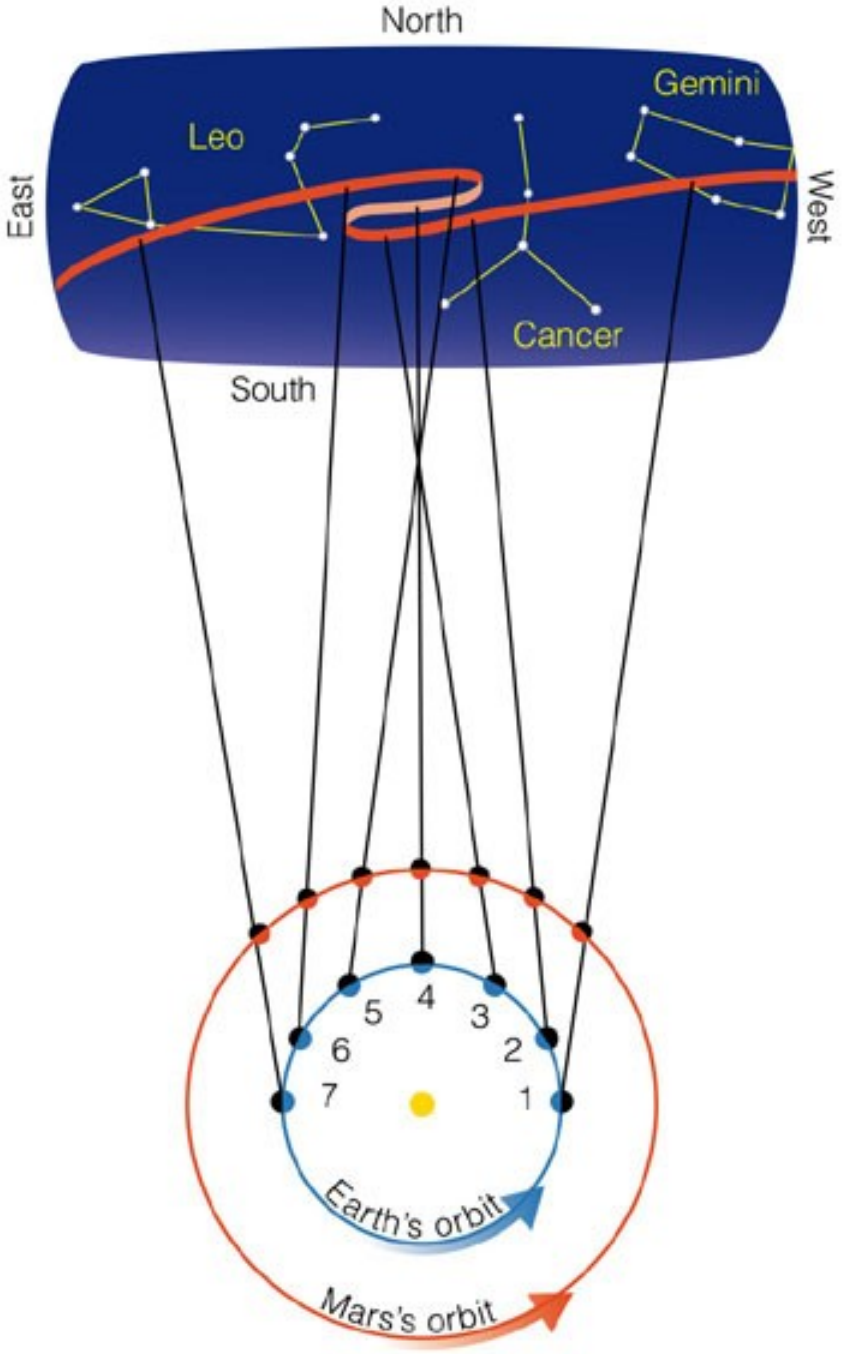
Motion of Mars on the Sky



Earth-Centered Model



Ptolemy (150 A.D.) introduced the idea of epicycles to explain the motion of the planets



Sun-Centered Model

Copernicus (1500 A.D.) suggested that it would be simpler to have the planets orbit the Sun. (demo 8A10.55)

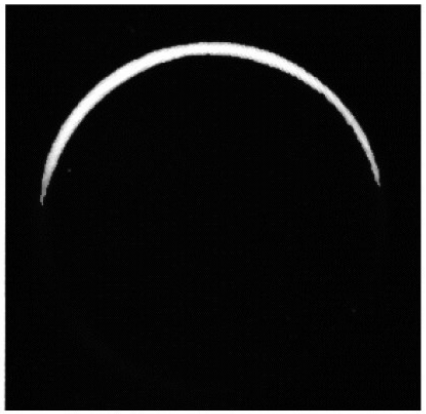
Moves Earth from center of Universe.

Copernican principle – we do not occupy a special place in the Universe.

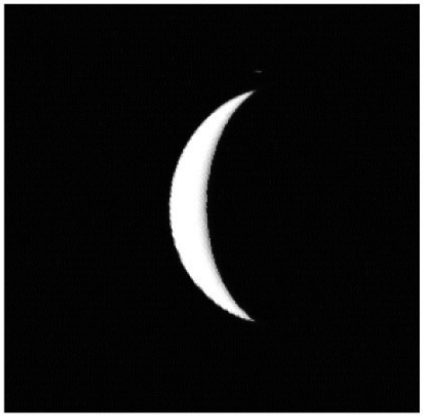
Any way to pick between models of Ptolemy vs Copernicus?

Predictions of the positions of the planets on the sky are essentially the same.

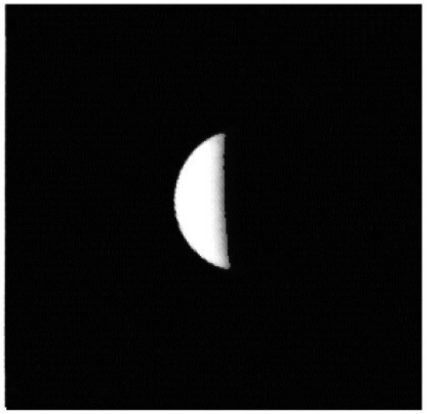
Galileo proved the planets orbit the Sun by observing Venus



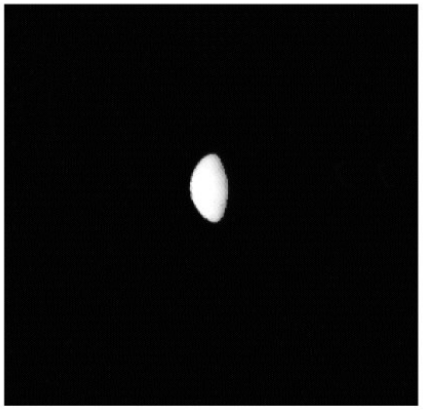
$\alpha = 58°$



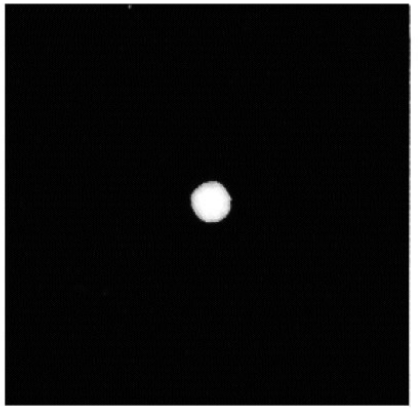
$\alpha = 42°$



$\alpha = 24°$



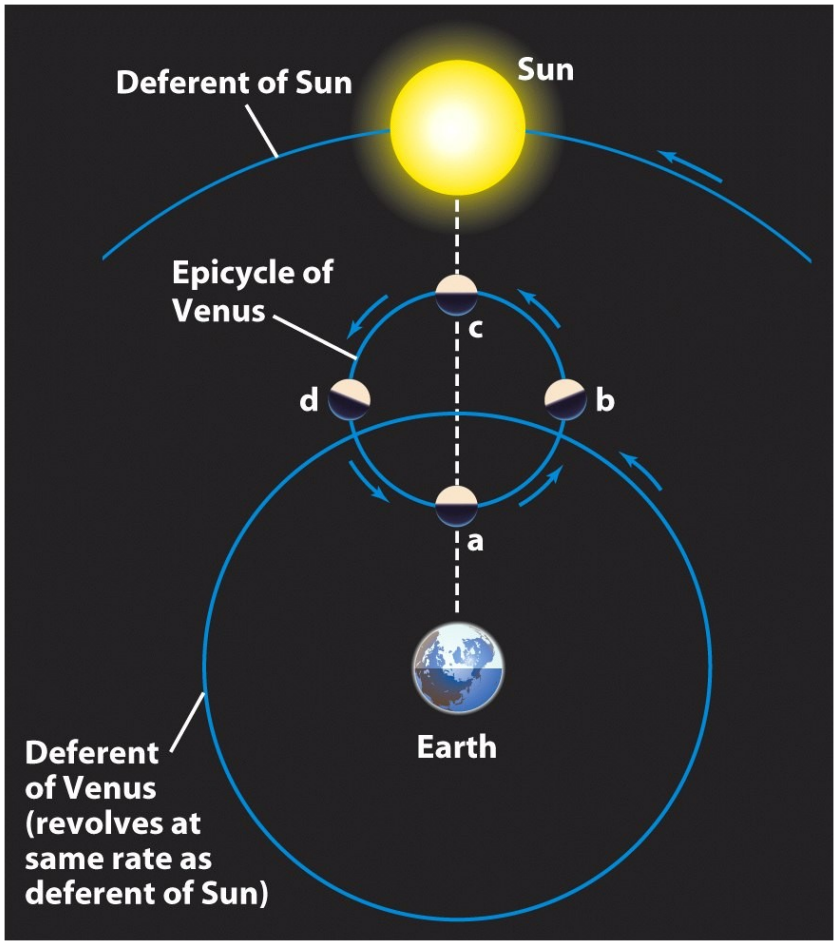
$\alpha = 15°$



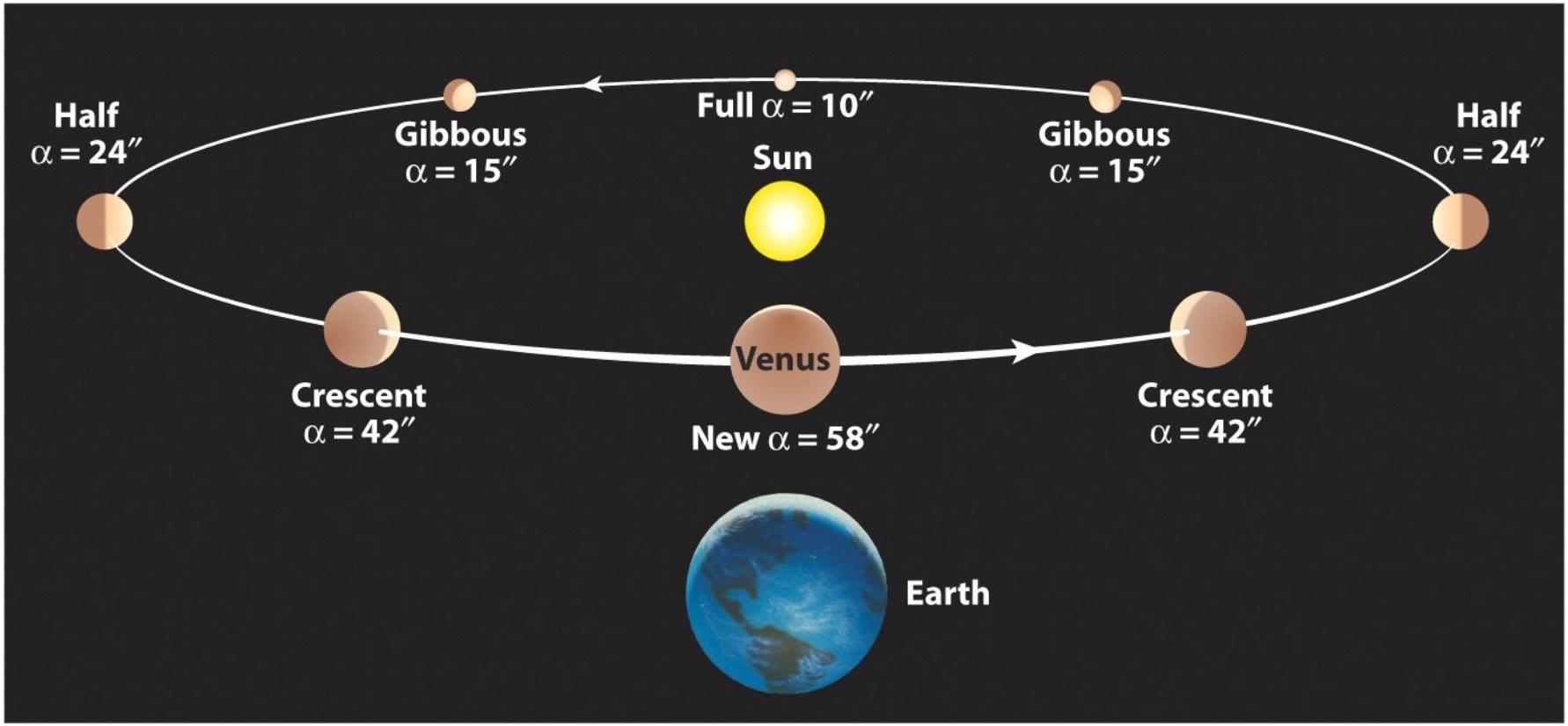
$\alpha = 10°$

Earth-Centered Model

- Venus is never seen very far from the Sun.
- In Ptolemy's model, Venus and the Sun must move together with the epicycle of Venus centered on a line between the Earth and the Sun
- Then, Venus can never be the opposite side of the Sun from the Earth, so it can never have gibbous phases – no "full Venus".



Sun-Centered Model



- In a Sun centered model, Venus can show all phases – as Galileo observed.

Retrograde motion is explained in the Copernican (sun-centered) model of the solar system as

A) a result of planets moving in circles in constant speed around the Sun

B) an illusion that takes place when a planet is at its maximum distance from the Sun

C) when a planet slows down when at large distances from the Sun

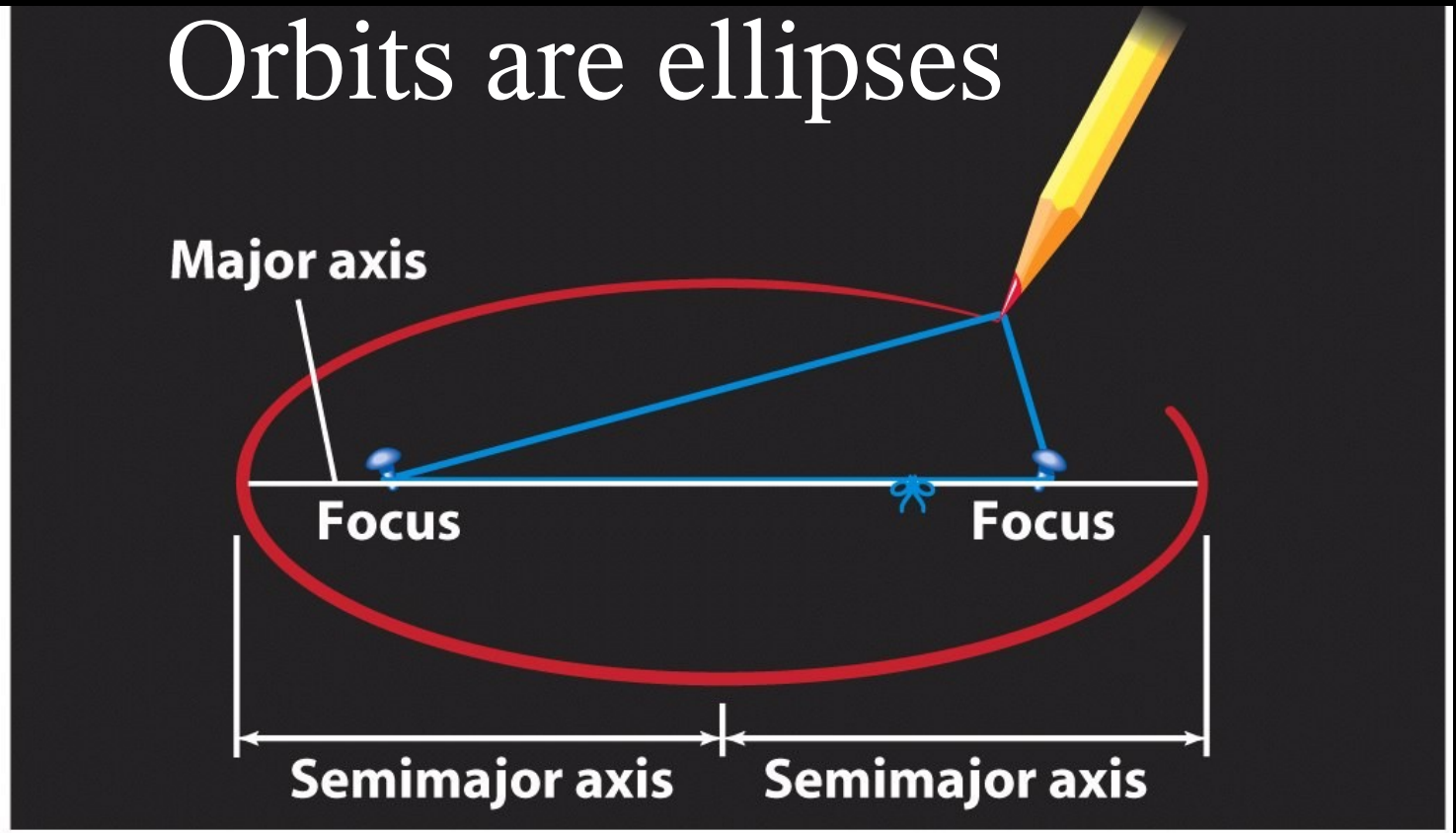
D) a dance move

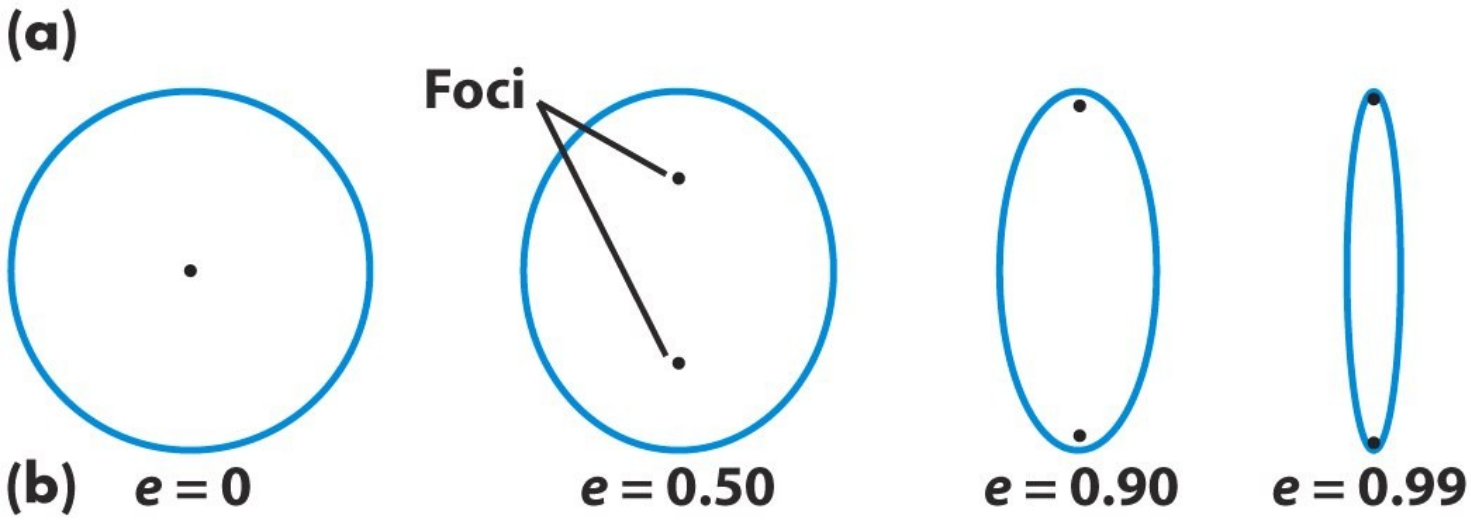
Kepler's Laws of Planetary Motion

- Copernicus' model makes slightly wrong predictions about the positions of the planets in the sky.
- Using precise measurements of the positions of the planets in the sky collected by Tycho Brahe, Johannes Kepler deduced three laws of planetary motion:

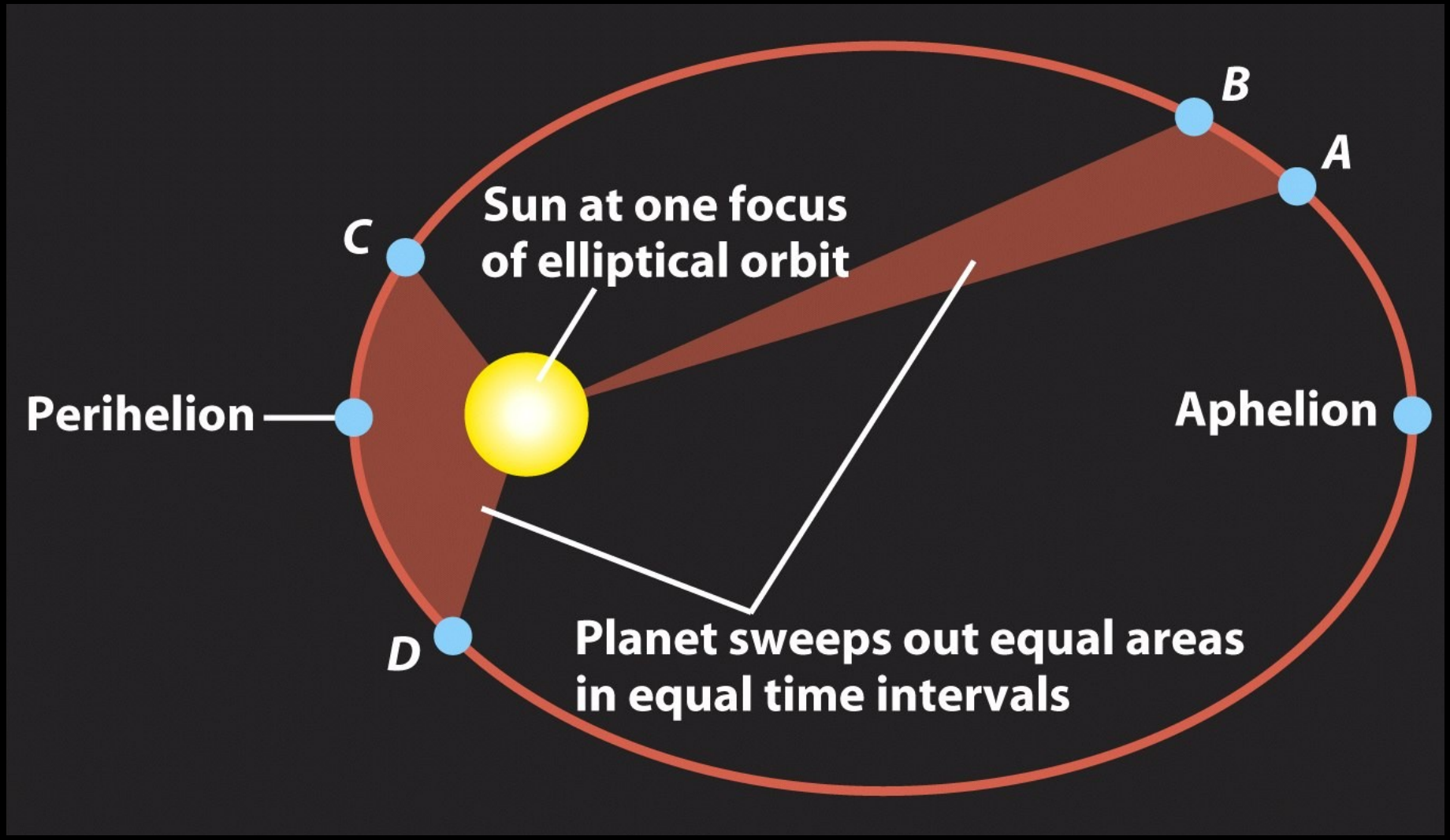
– The orbits are ellipses.
– Planets move faster when closer to the Sun and slower when farther away.
– Planets farther from the Sun take longer to orbit.

Orbits are ellipses

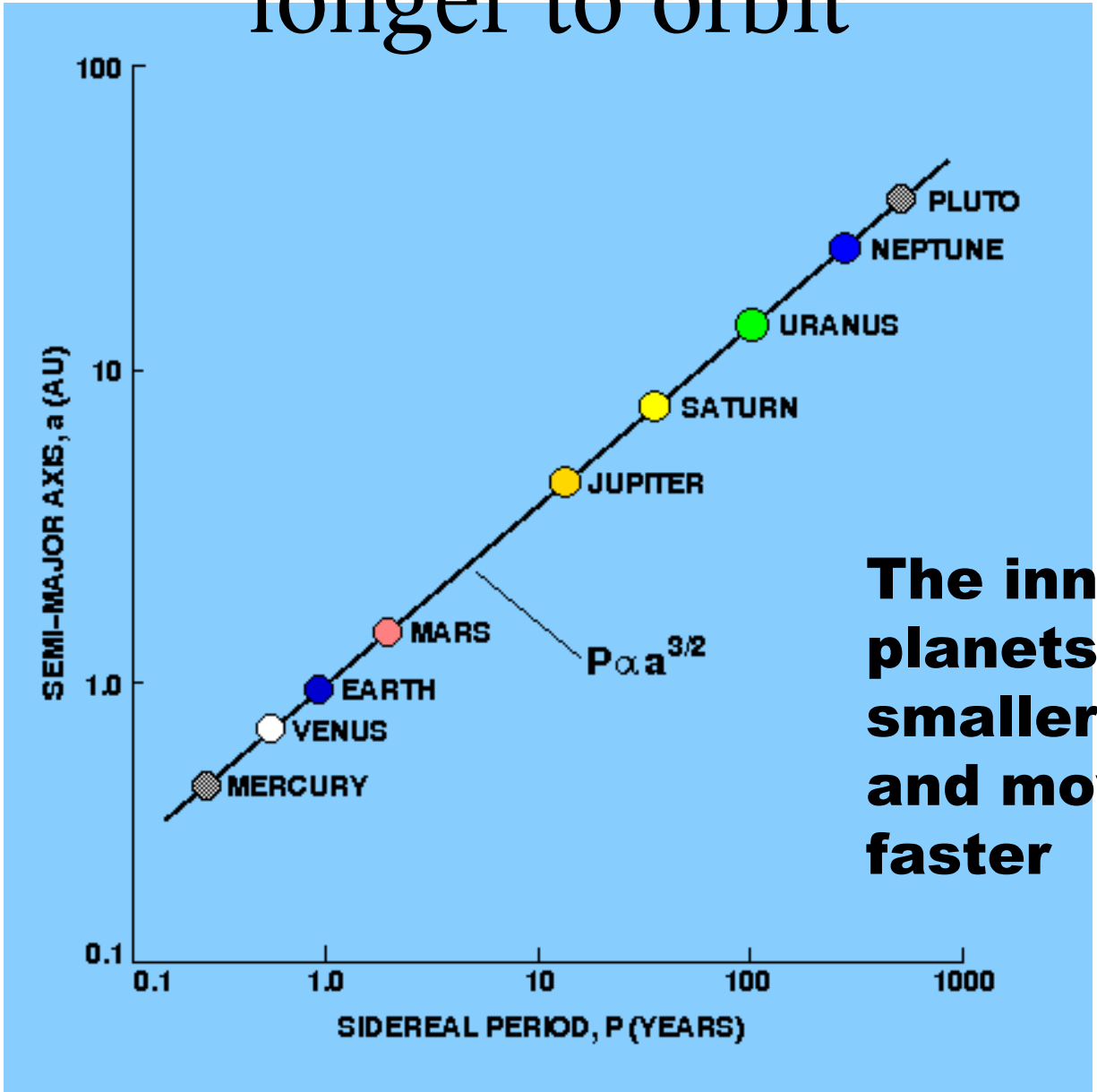




Planets move faster when closer to the Sun

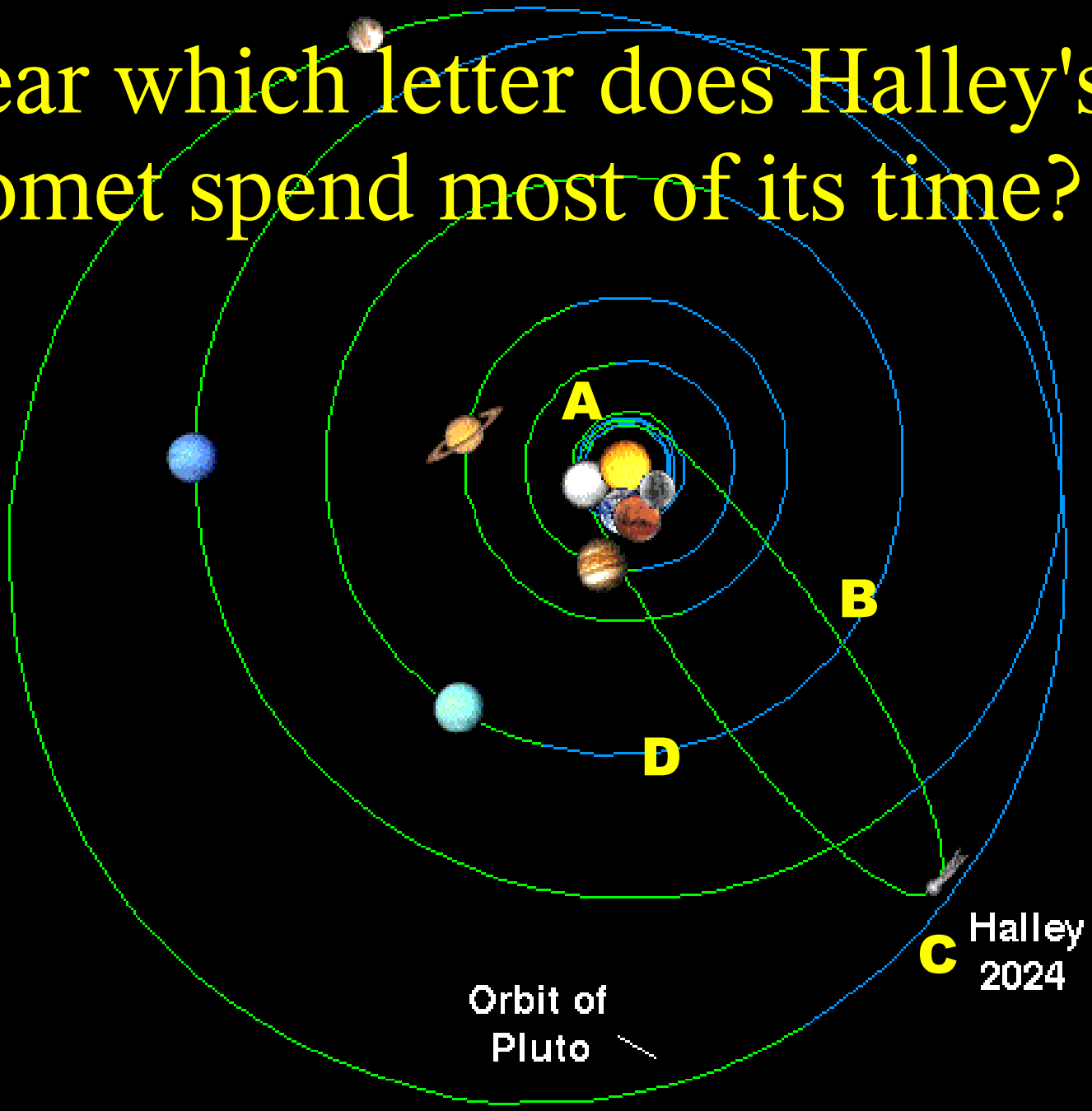


Planets farther from the Sun take longer to orbit



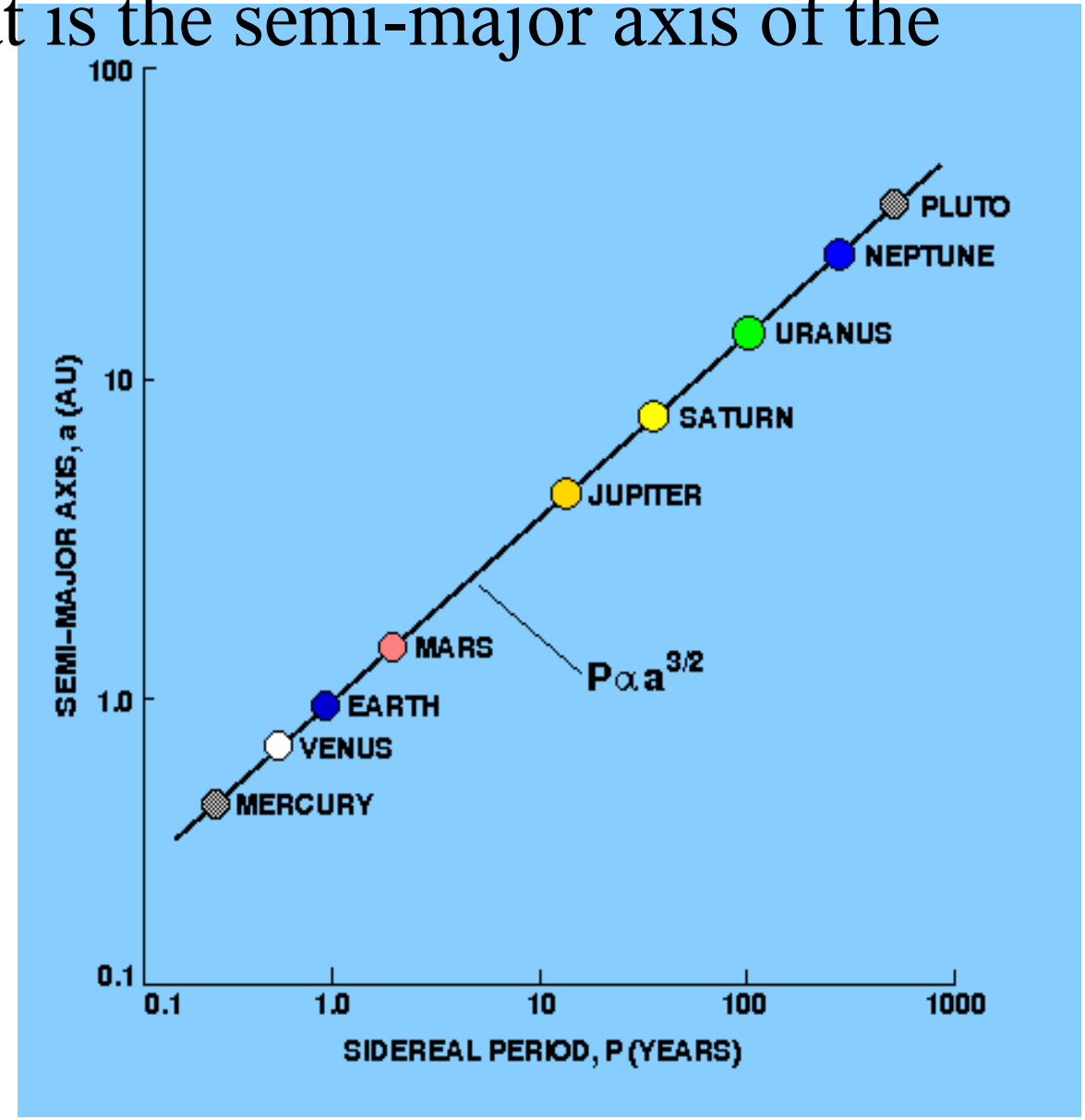
The inner planets have smaller orbits and move faster

Near which letter does Halley's comet spend most of its time?



Halley's comet has an orbital period of about 80 years. What is the semi-major axis of the orbit?

A) 0.2
B) 2 AU
C) 20 AU
D) 200 AU
E) No clue



Isaac Newton

- Newton realized that the same physical laws which apply on Earth also apply to the Sun, Moon, and planets.
- He formulated laws that described the motion of objects both on Earth and in space (the heavens).
- He also invented calculus.

Newton's laws

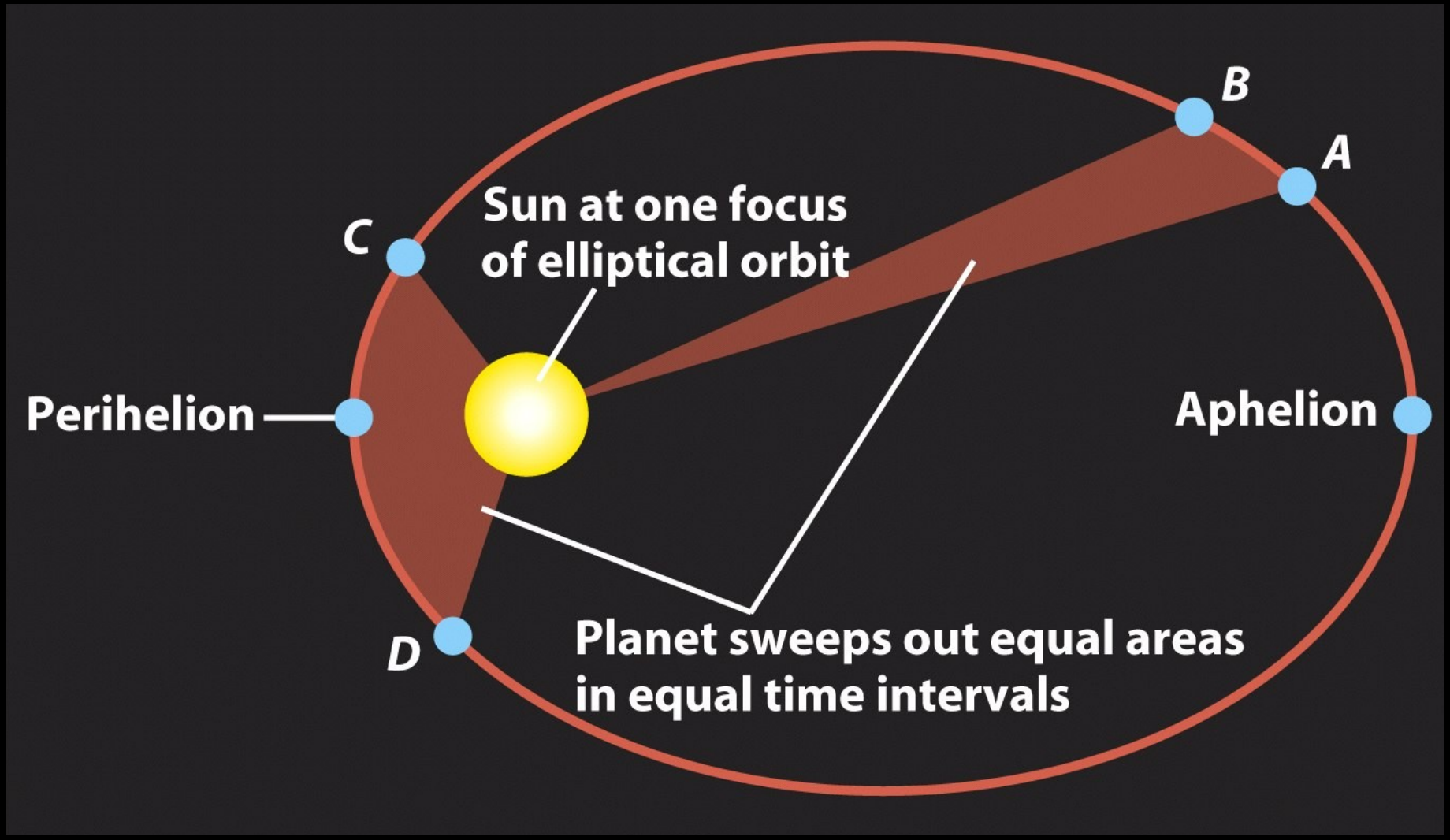
1. The law of inertia: a body remains at rest, or moves in a straight line at a constant speed, unless acted upon by an outside force
2. The force on an object is directly proportional to its mass and acceleration.
3. The principle of action and reaction: whenever one body exerts a force on a second body, the second body exerts an equal and opposite force on the first body.

Newton's Law of Gravitation

- The gravitational force exerted by an object is proportional to its mass
- The gravitational force exerted by an object decreases with the square of the distance
  - If person B is twice as far away from the Sun as person A, then the force of gravity on person B is only ¼ of that on person A.

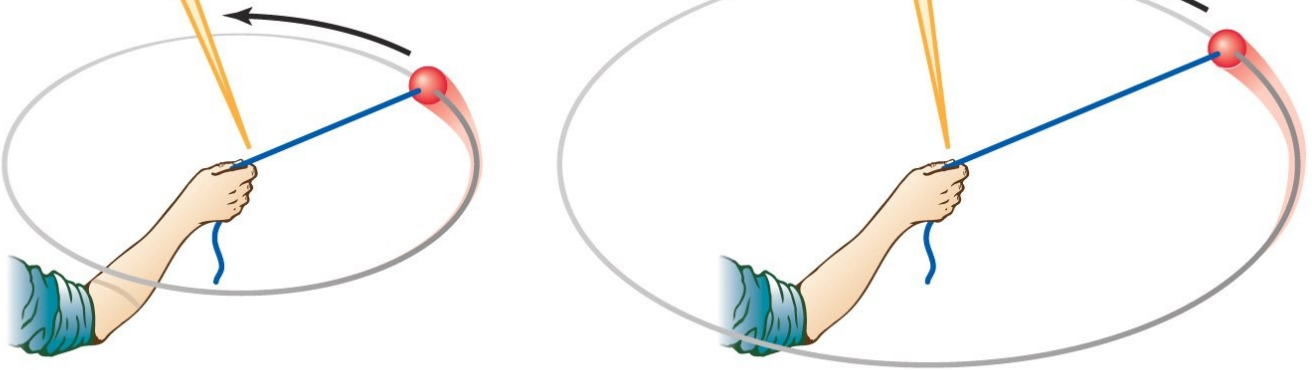
Newton's laws explain Kepler's laws

Planets move faster when closer to the Sun



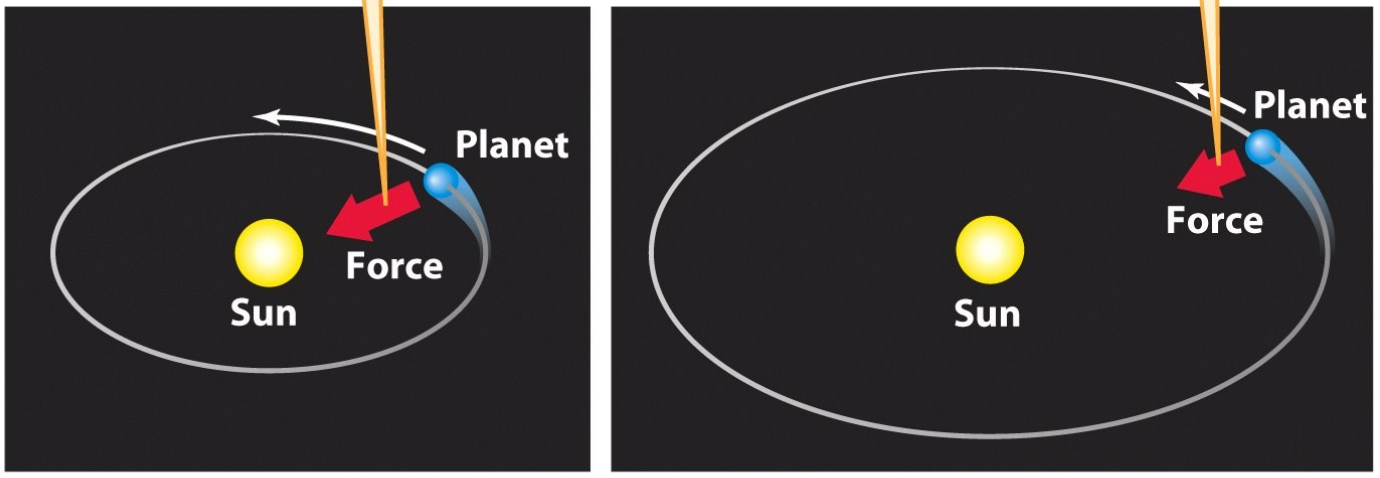
To make a ball move at a high speed in a small circle requires a strong pull.

To make the same ball move at a low speed in a large circle requires only a weak pull.

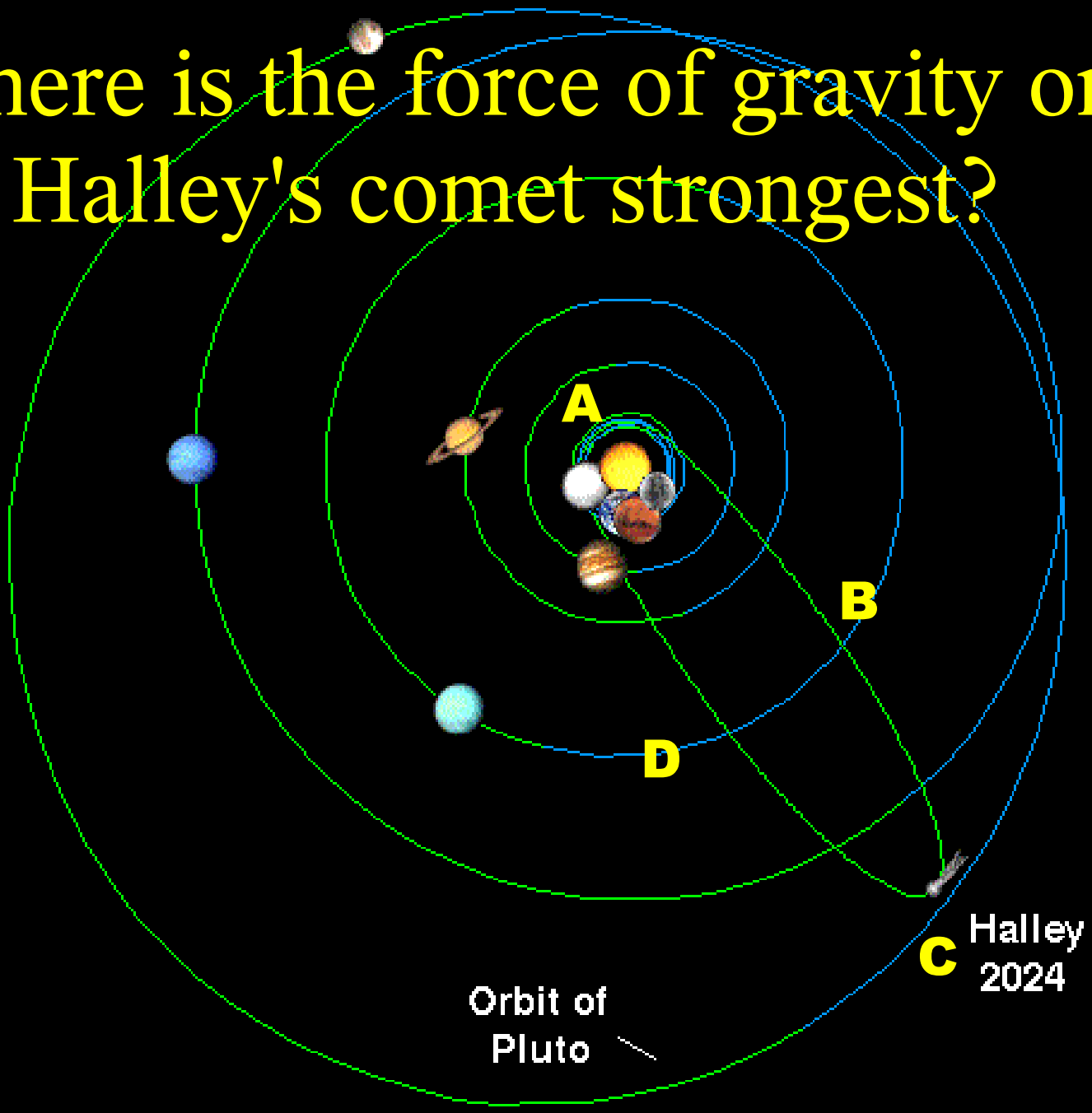


To make a planet move at a high speed in a small orbit requires a strong gravitational force.

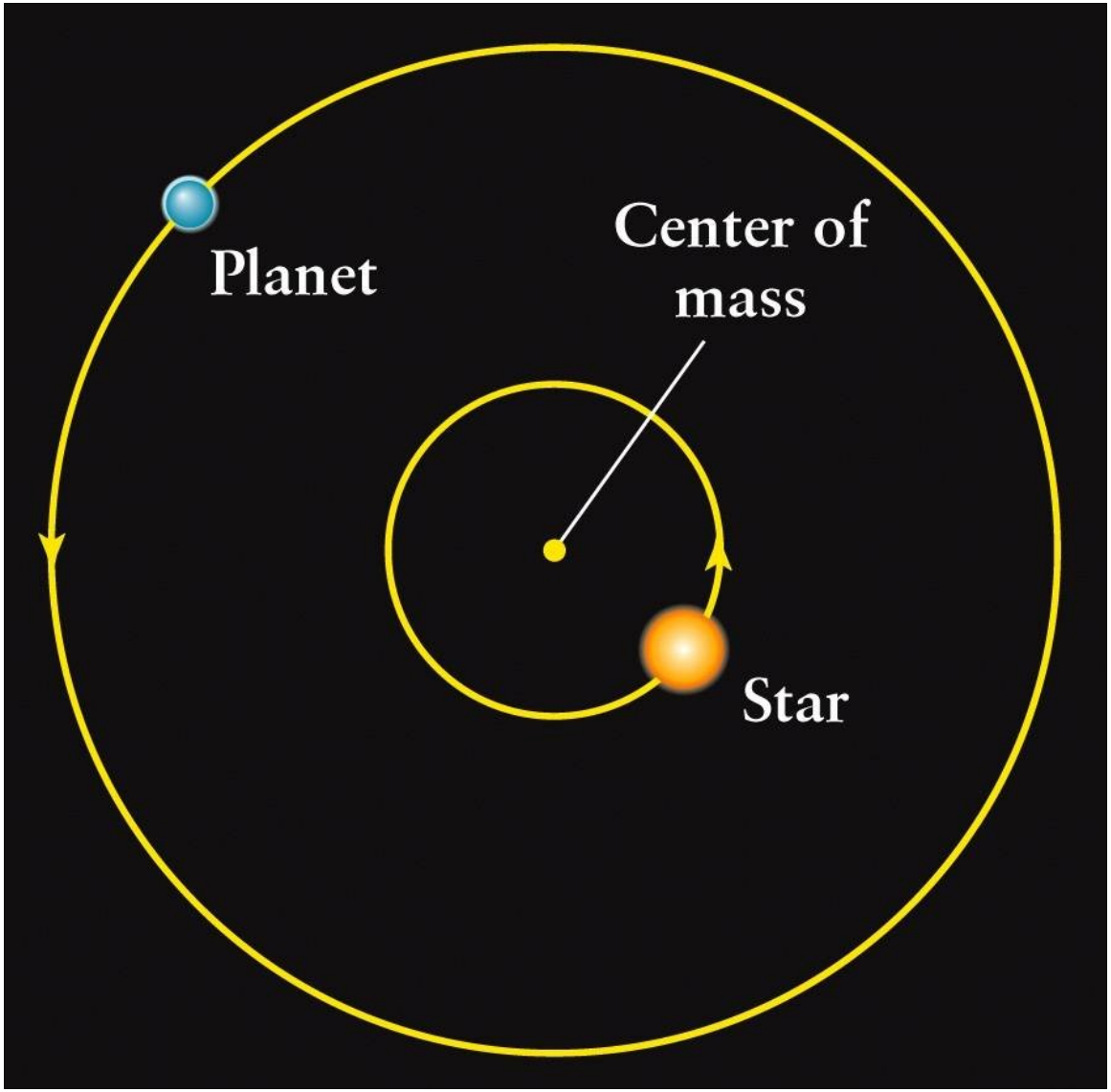
To make the same planet move at a low speed in a larger orbit requires only a weak gravitational force.



Where is the force of gravity on Halley's comet strongest?



Mutual orbits of planet and star



Review Questions

- What is an epicycle?
- What was the flaw in Copernicus's heliocentric model of the solar system?
- What did Galileo observe about Venus and why is it important?
- Does Pluto orbit faster or slower than Mercury. How did Newton explain this?