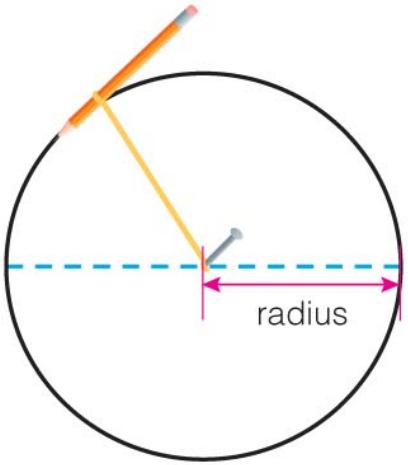
How did Copernicus, Tycho, and Kepler challenge the Earth-centered model?

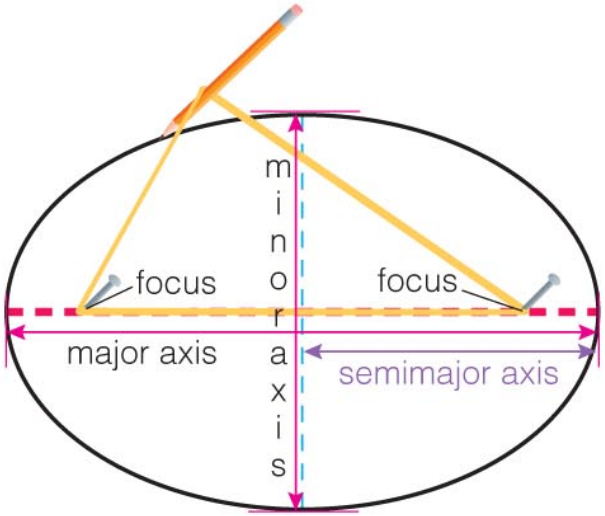
Johannes Kepler
(1571-1630)

- Kepler first tried to match Tycho's observations with circular orbits
- But an 8-arcminute discrepancy led him eventually to ellipses.
- *"If I had believed that we could ignore these eight minutes [of arc], I would have patched up my hypothesis accordingly. But, since it was not permissible to ignore, those eight minutes pointed the road to a complete reformation in astronomy."*

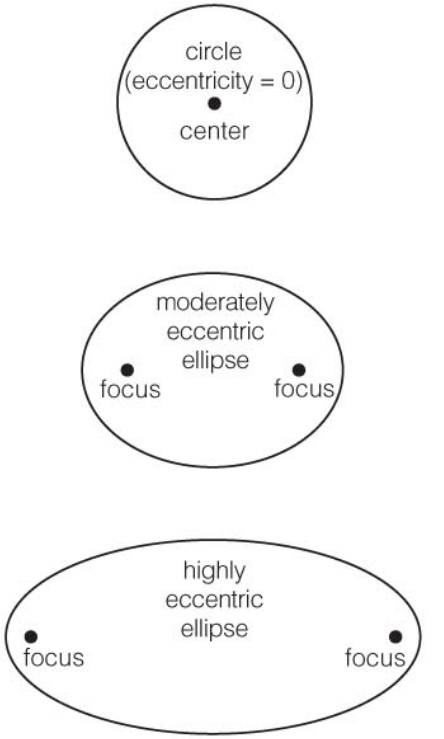
What is an ellipse?



a Drawing a circle with a string of fixed length.



b Drawing an ellipse with a string of fixed length.

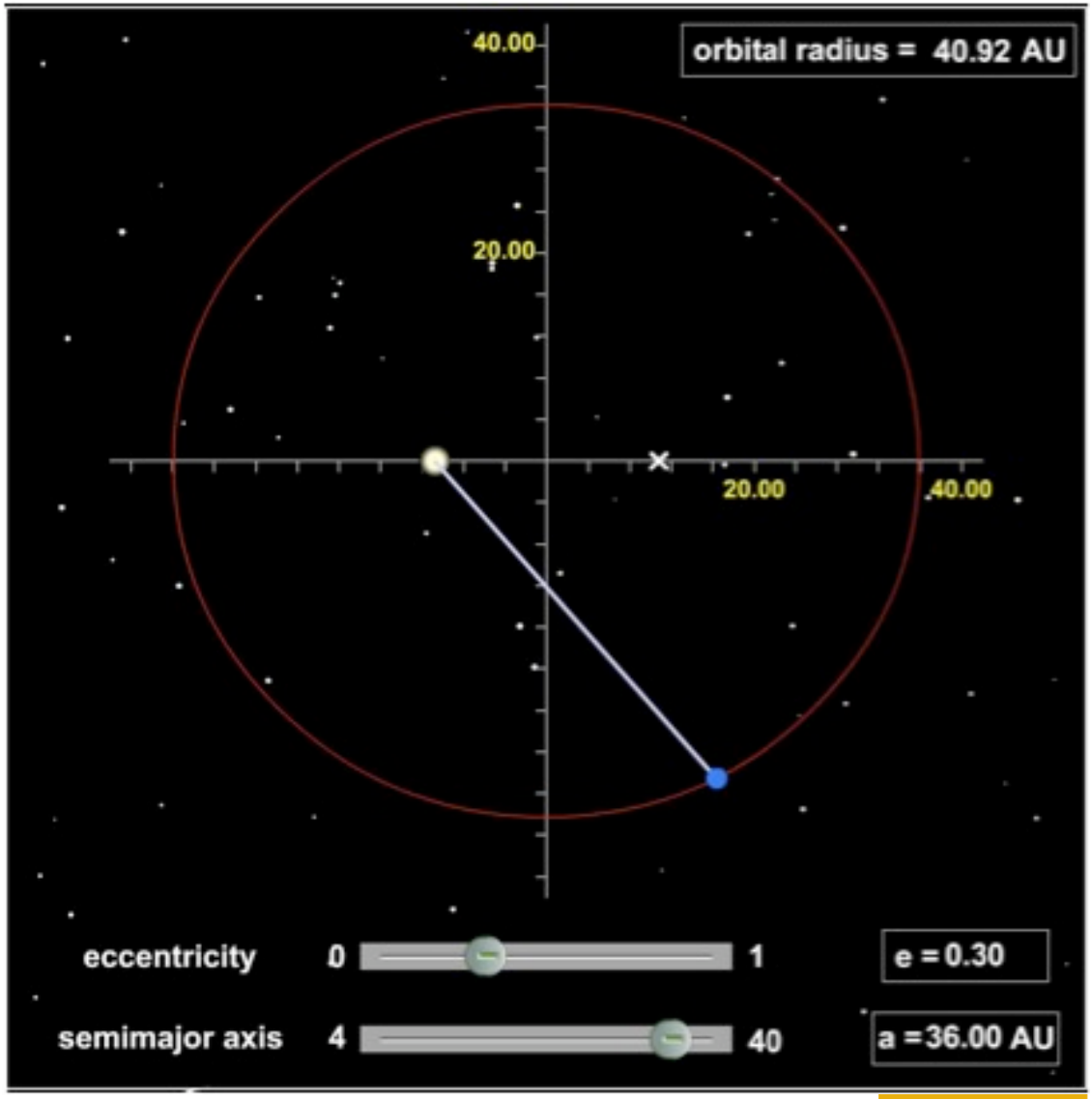


c Eccentricity describes how much an ellipse deviates from a perfect circle.

Interactive Figure

An ellipse looks like an elongated circle.

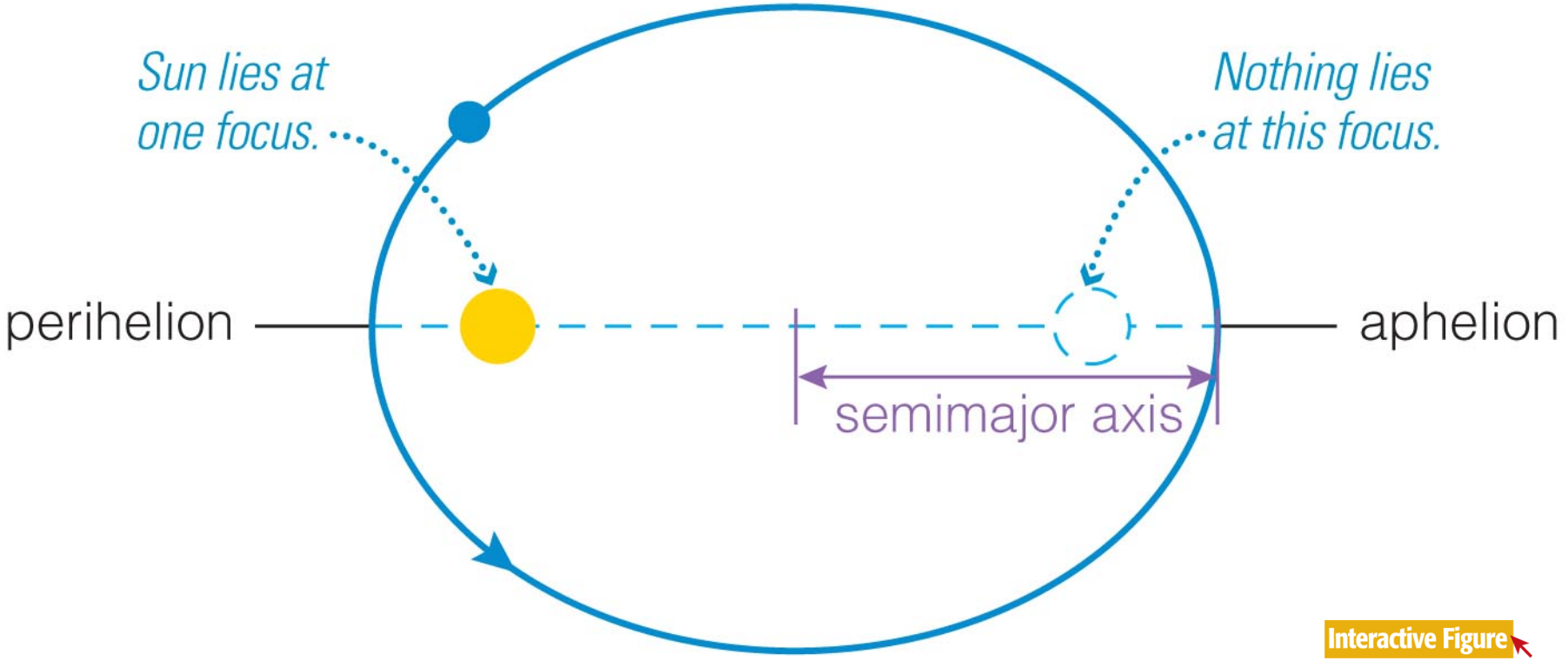
Eccentricity of an Ellipse



Interactive Figure

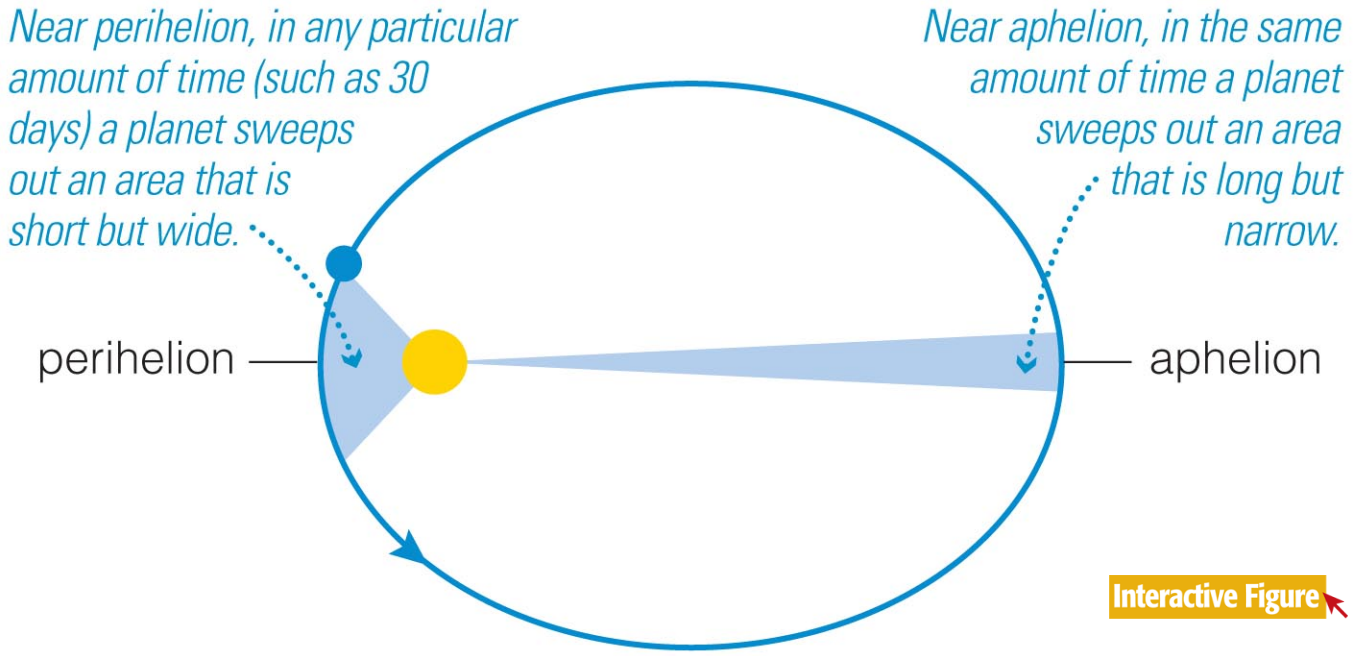
What are Kepler's three laws of planetary motion?

- **Kepler's First Law:** The orbit of each planet around the Sun is an ***ellipse*** with the Sun at one focus.



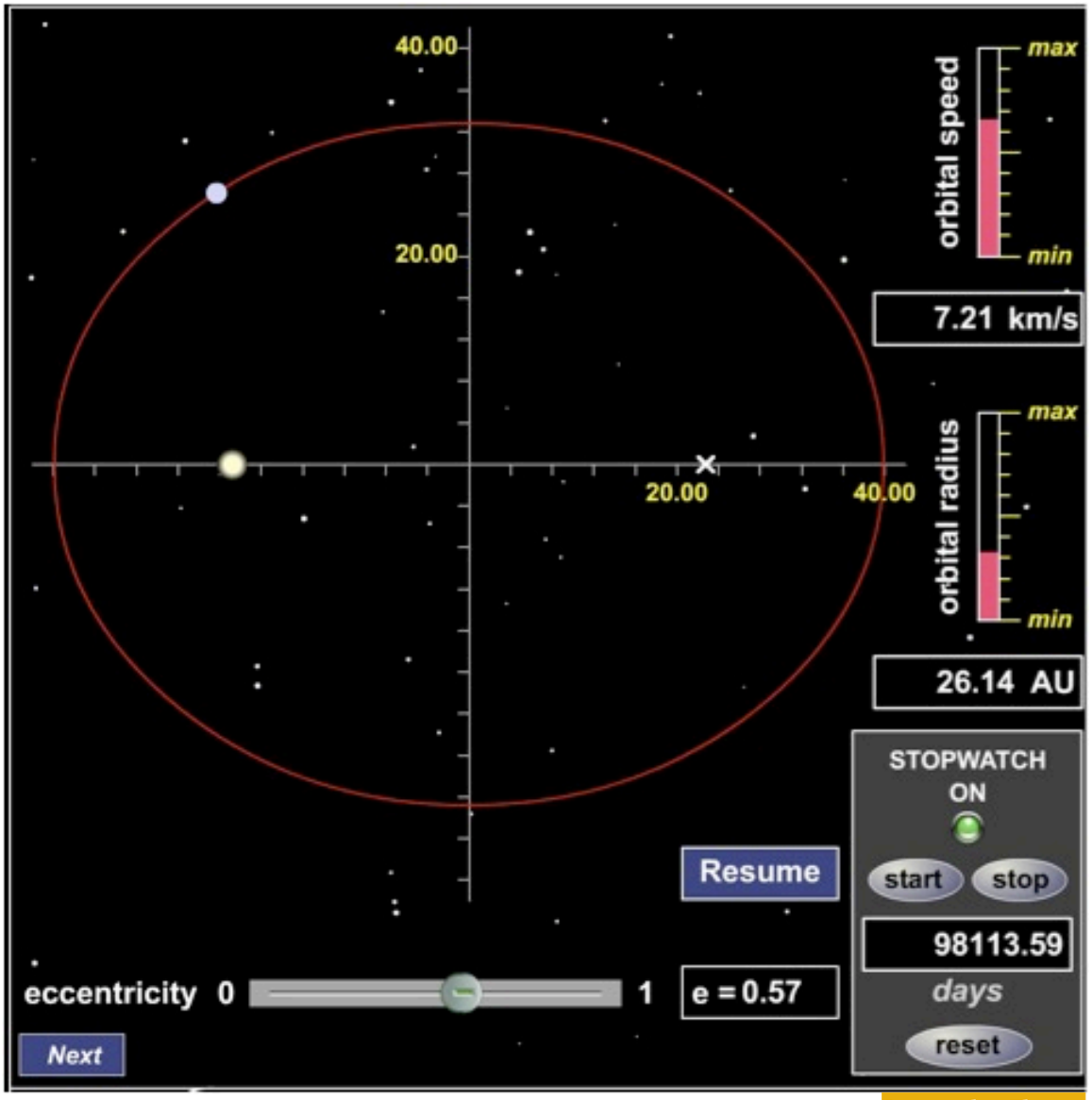
What are Kepler's three laws of planetary motion?

- **Kepler's Second Law:** As a planet moves around its orbit, it sweeps out equal areas in equal times.



This means that a planet travels faster when it is nearer to the Sun and slower when it is farther from the Sun.

What are Kepler's three laws of planetary motion?



Interactive Figure

Kepler's Third Law

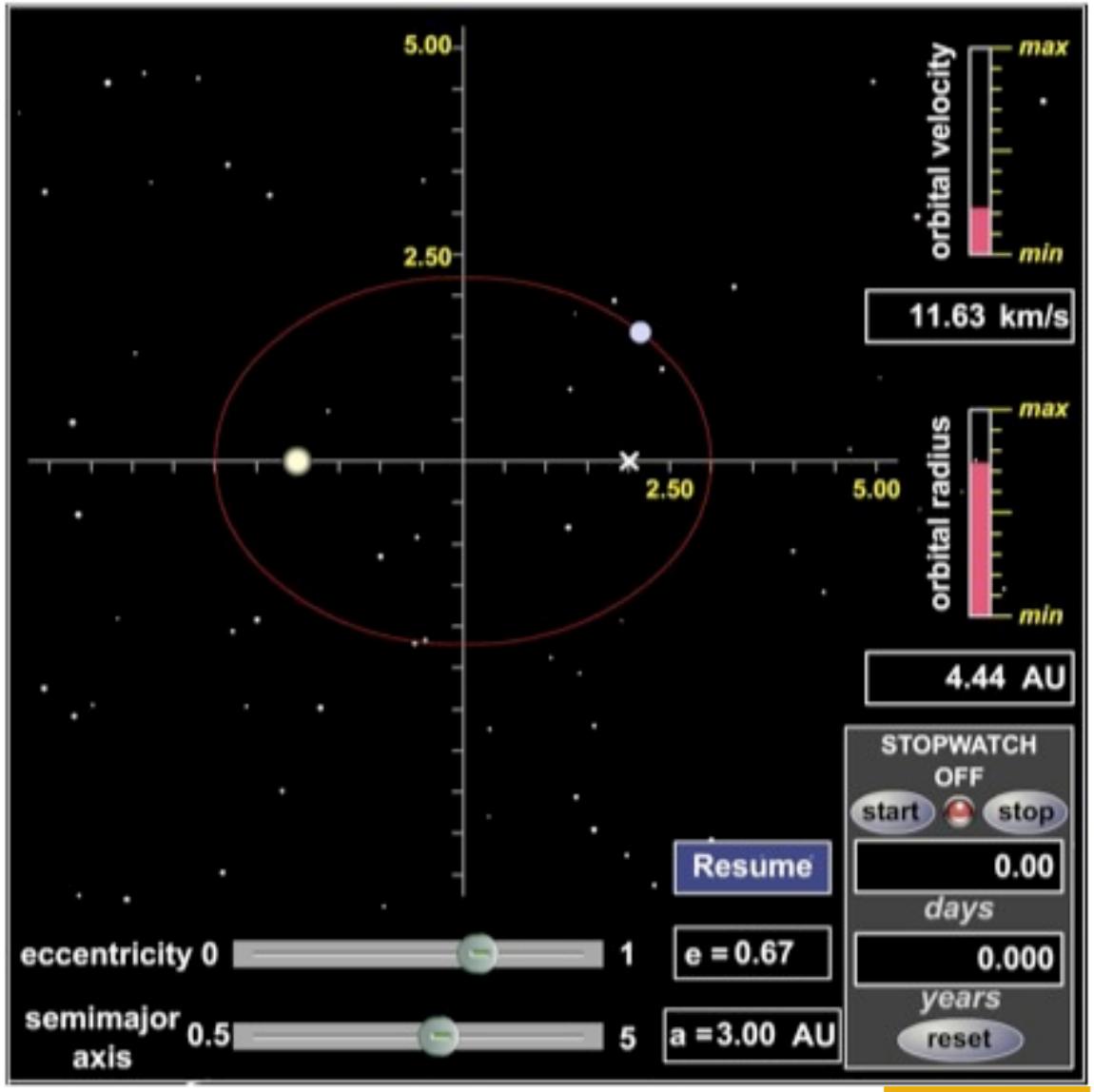
- More distant planets orbit the Sun at slower average speeds, obeying the relationship

$$p^2 = a^3$$

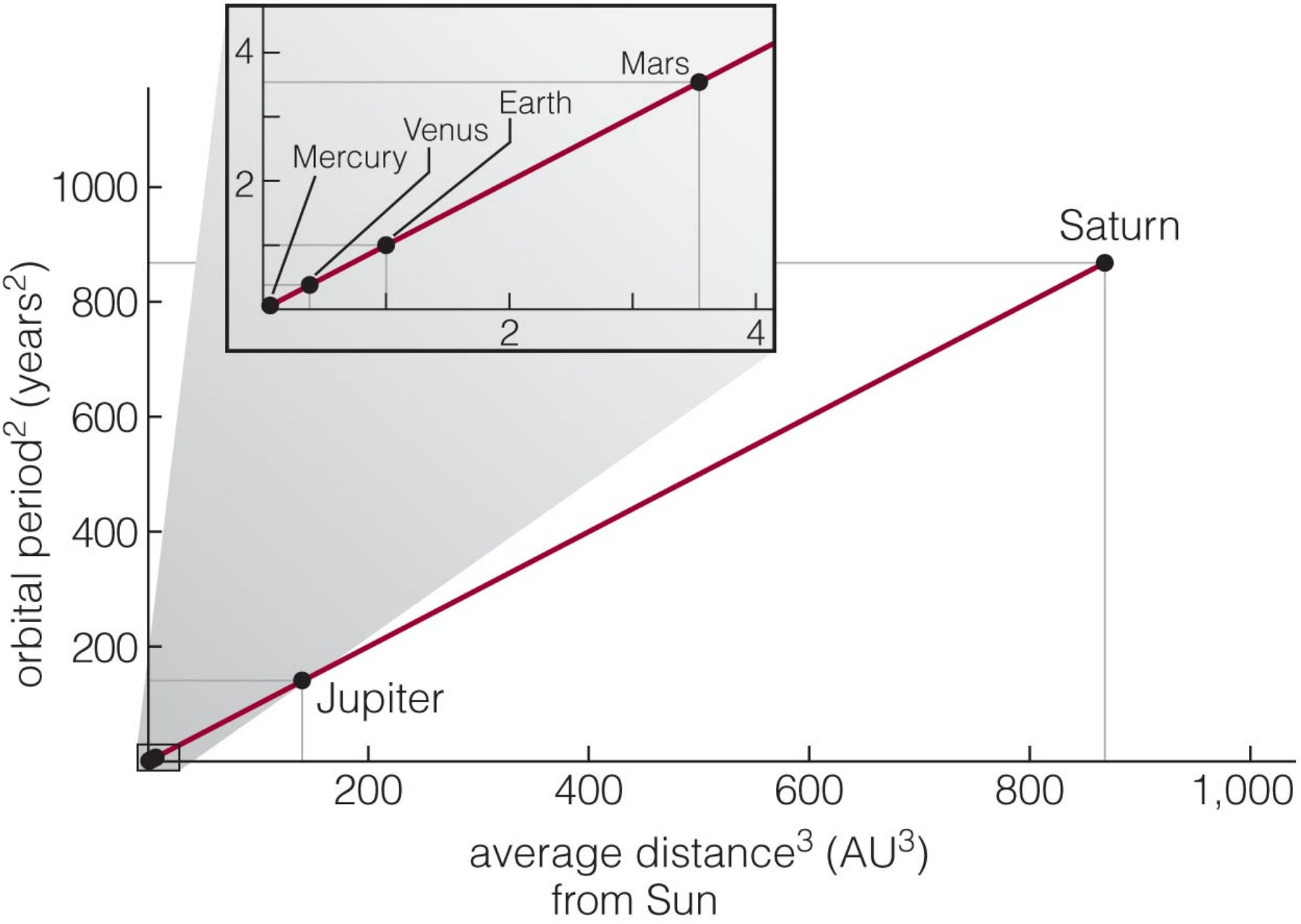
p = orbital period in years

a = avg. distance from Sun in AU

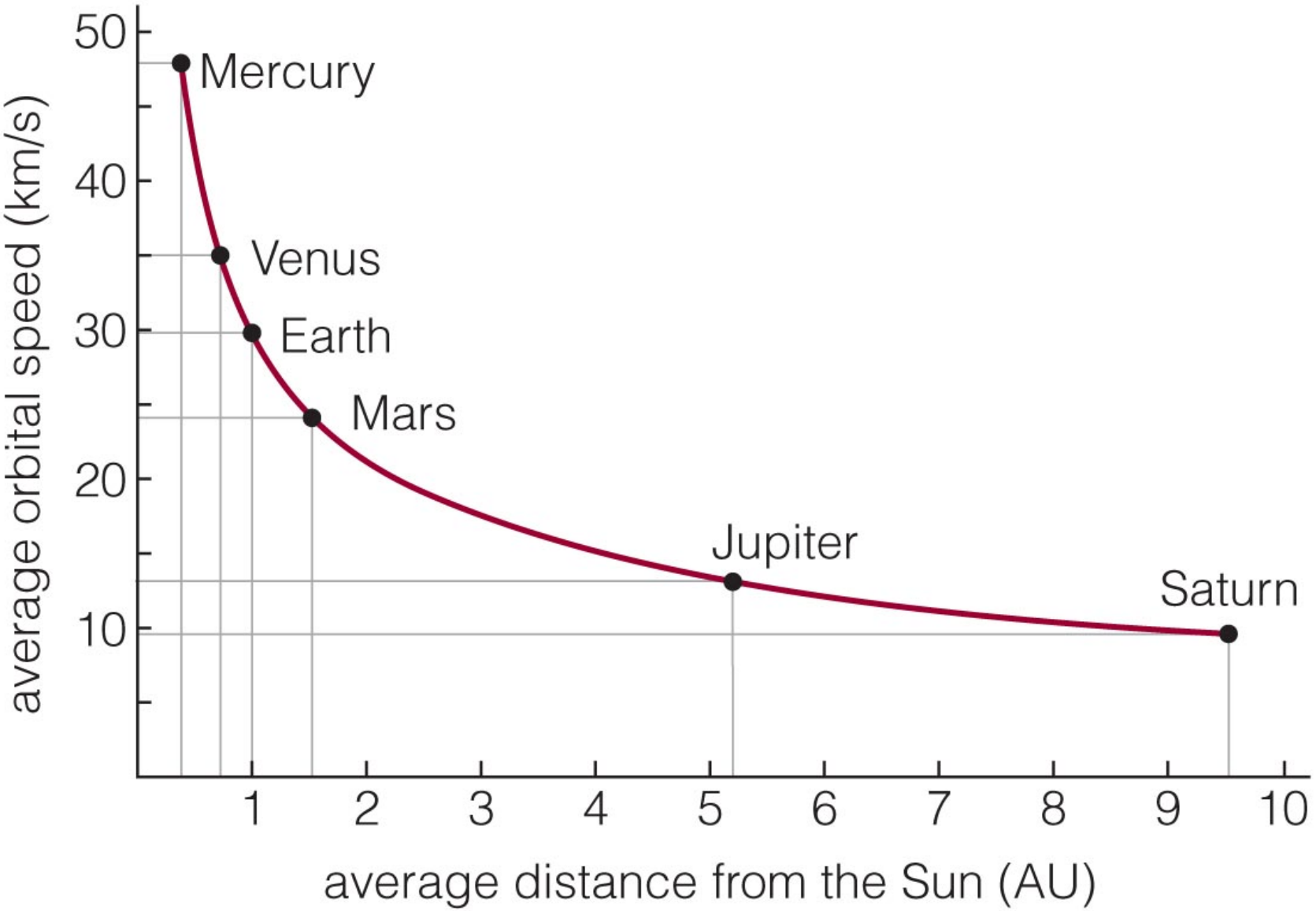
Kepler's Third Law



Kepler's Third Law



Kepler's Third Law



Thought Question

An asteroid orbits the Sun at an average distance a = 4 AU. How long does it take to orbit the Sun?

A. 4 years

B. 8 years

C. 16 years

D. 64 years

Hint: Remember that $p^2 = a^3$

Thought Question

An asteroid orbits the Sun at an average distance a = 4 AU. How long does it take to orbit the Sun?

A. 4 years

B. 8 years

C. 16 years

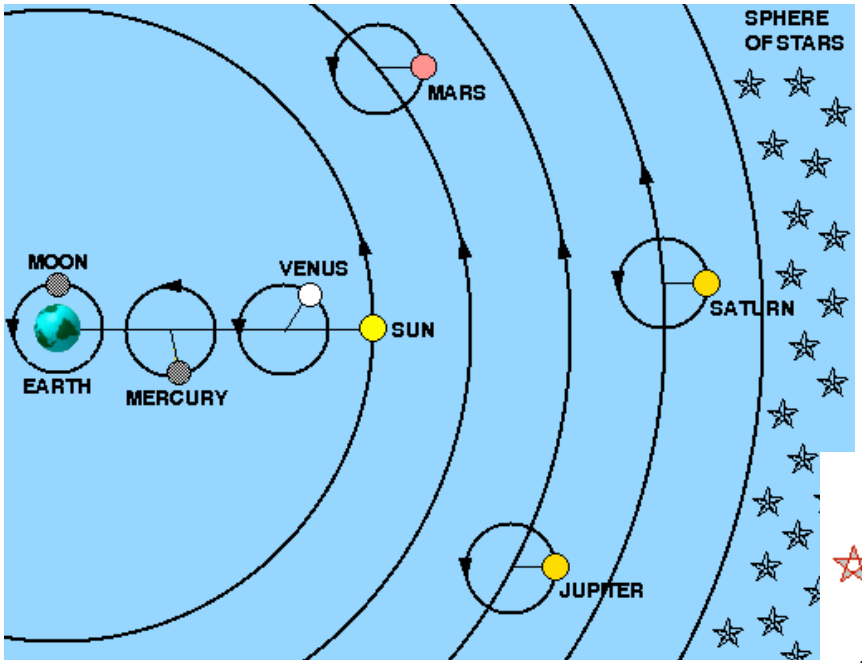
D. 64 years

We need to find p so that $p^2 = a^3$.

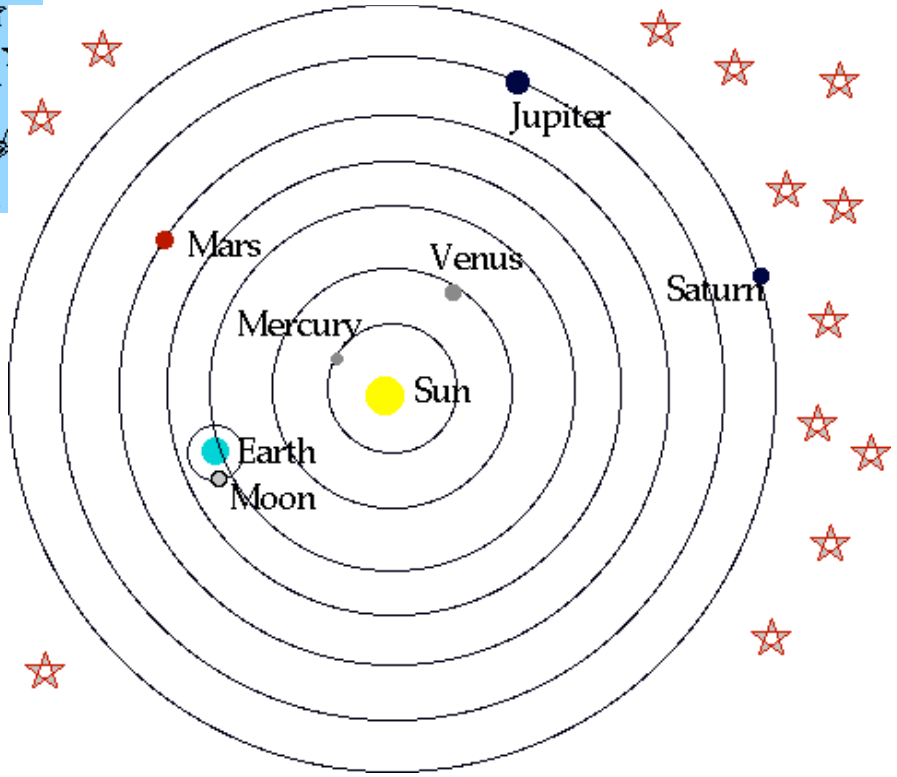
Since $a = 4$, $a^3 = 4^3 = 64$.

Therefore, $p = 8$, $p^2 = 8^2 = 64$.

Competing Models



The Ptolemaic system
(Geocentric)



The Copernican system
(Heliocentric)