Week 2 Thursday

Today's Agenda
- The Earth Moves!
- Astronomy becomes science and changes the universe
- Kepler's Laws & Gravity
- Basic Orbital Dynamics

Announcements / Reminders
- HW 1 due September 3rd at 11:59pm via Canvas upload

- Read Chapter 5 for next week
- HW 2 now available

Pre-Course Assessment Results

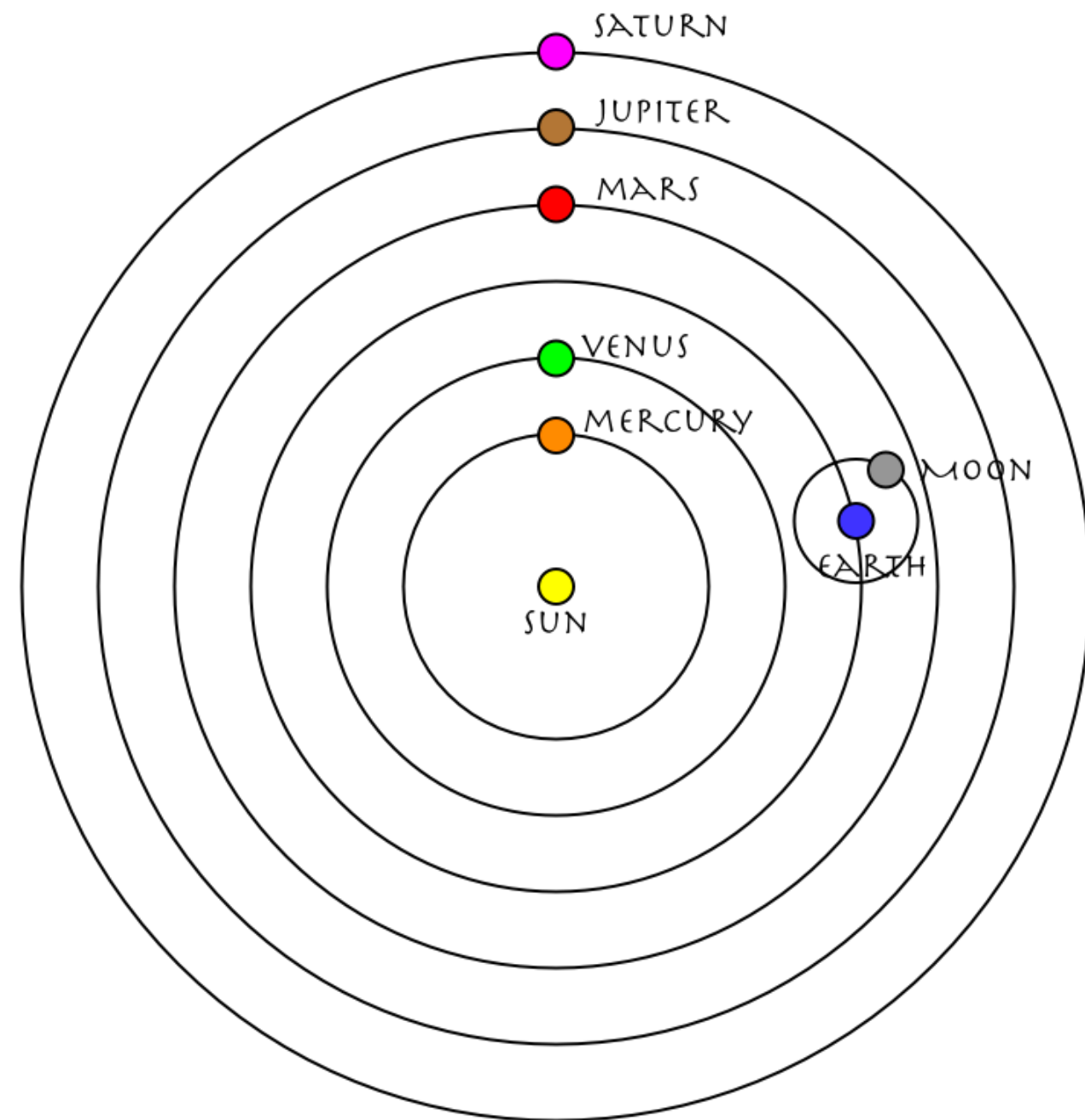F=ma   83%

L=r x p   55%

Doppler shift   86%

North Star   83%

Seasons   76%

Expanding Universe   38%

log(x)   86%

Sci. Notation   97%

Calc.   45%

Why are you taking the course?

Astro Emphasis (major): 65%

Astro Minor: 12%
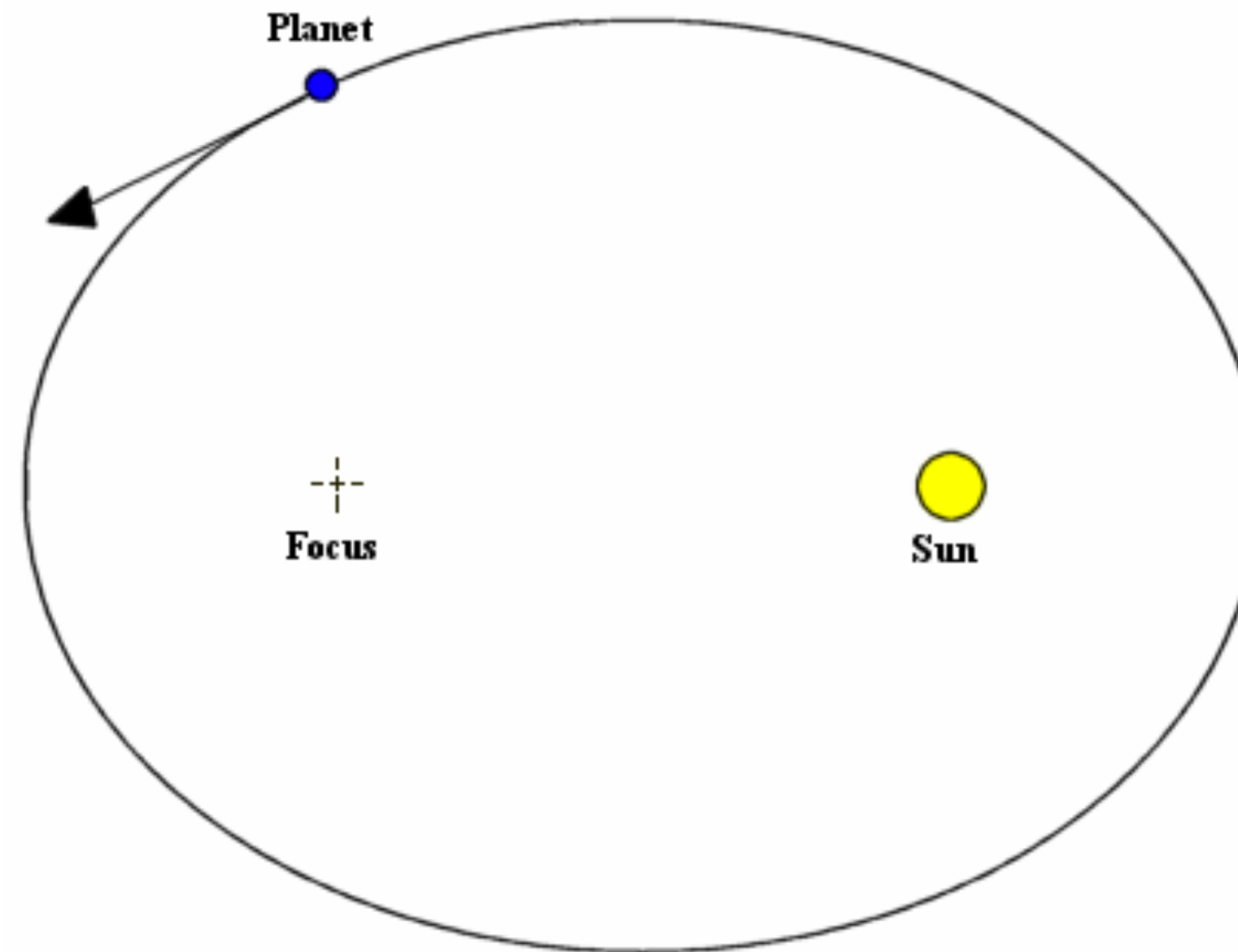
Req./Fun/Undecided: 23%

Effects of Earth's Motion

Astronomy becomes a Science

Heliocentric Model

Copernicus ➝ **Kepler** ➝ **Newton**

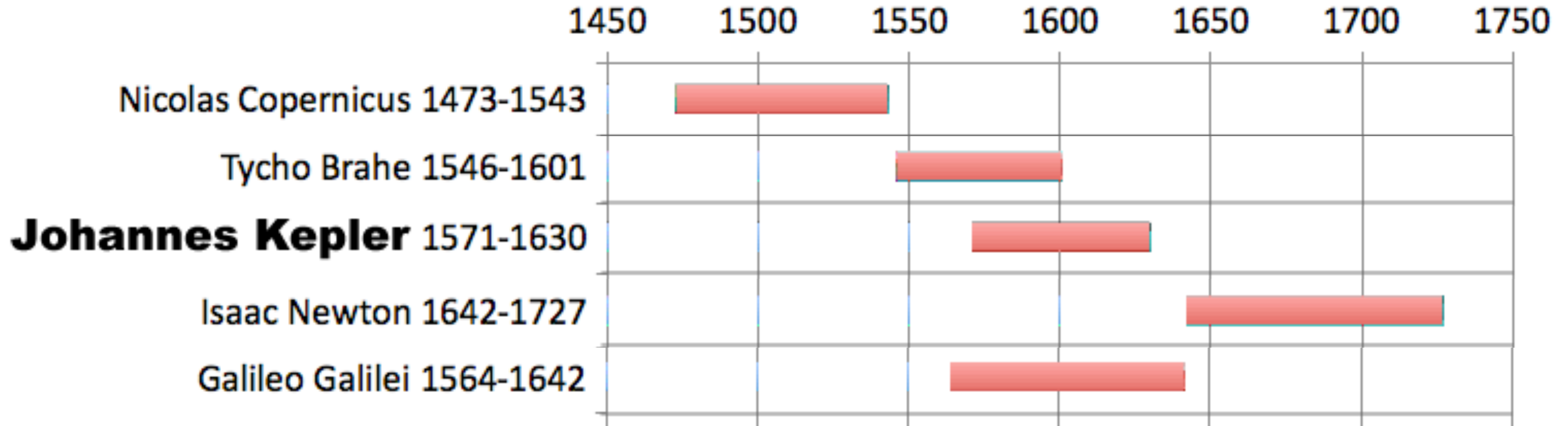Sun in the right place

Planetary paths mapped out correctly

Reason for paths explained theoretically
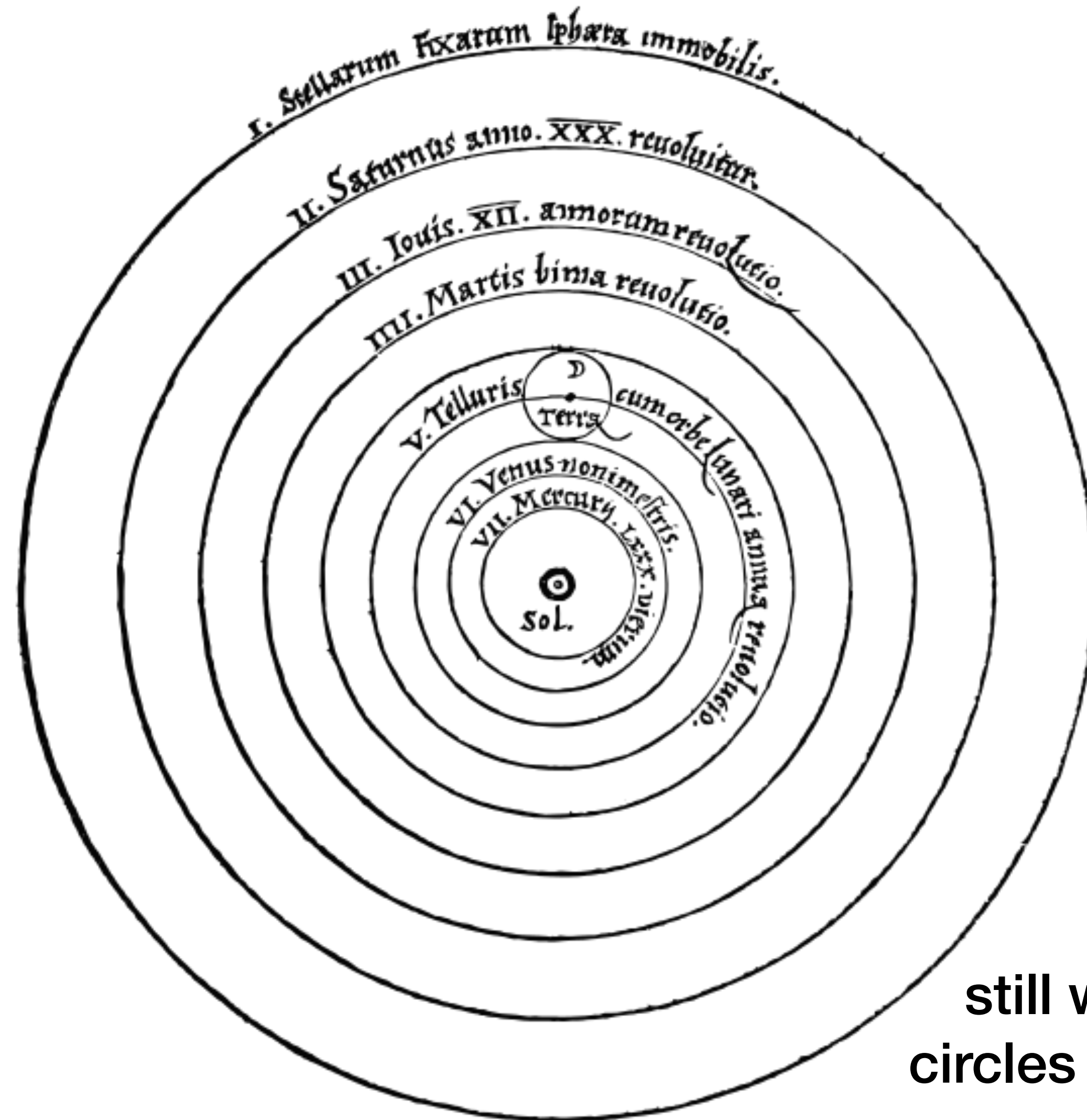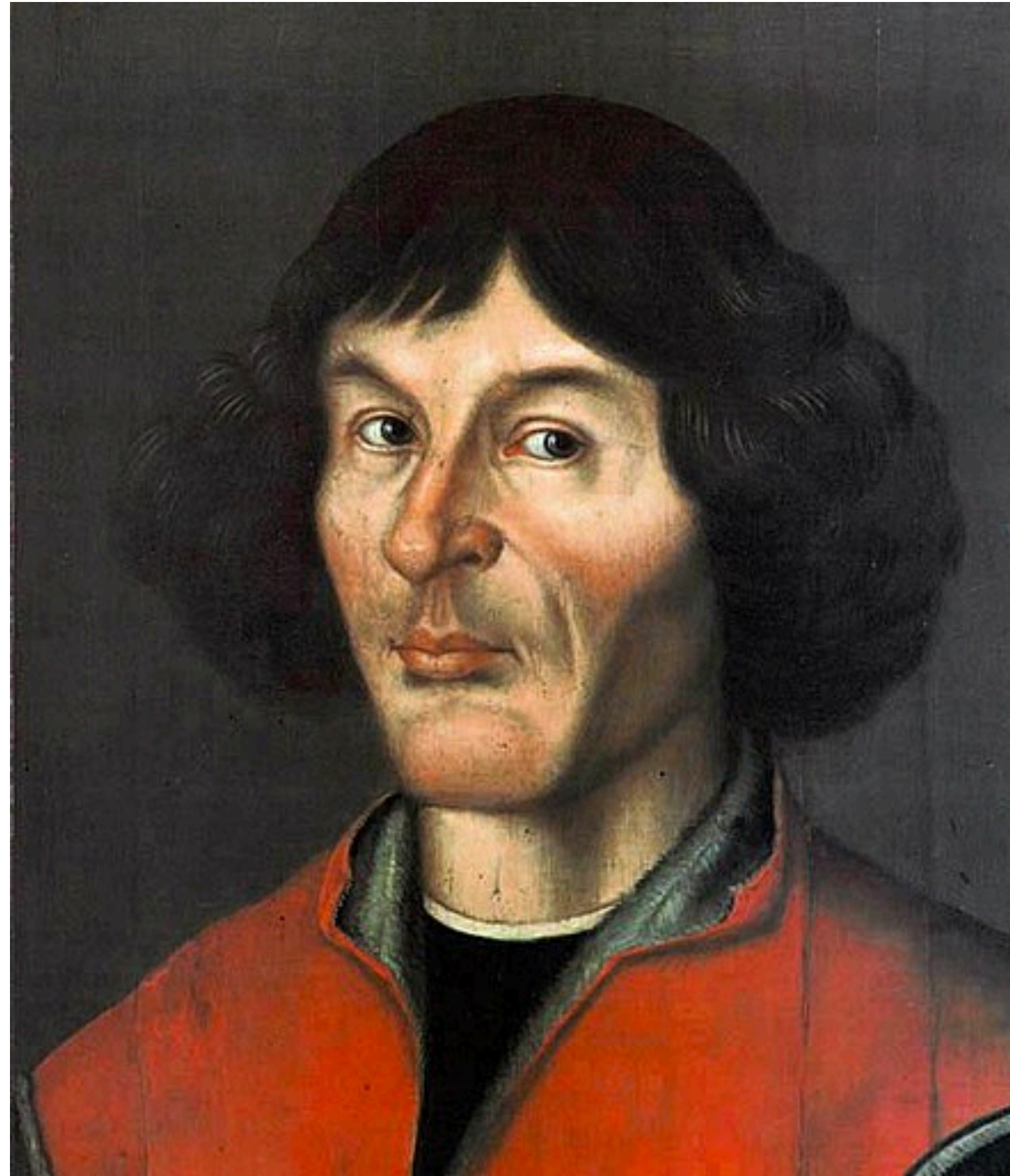
Astronomy leads to the development of physics

Invention of Science

Observations —> Model/Theory —> Predictions

Occam's Razor

	1450	1500	1550	1600	1650	1700	1750

Nicolas Copernicus 1473-1543

Tycho Brahe 1546-1601

Johannes Kepler 1571-1630

Isaac Newton 1642-1727

Galileo Galilei 1564-1642

Copernicus politely defies church orthodoxy (really just revisited 1700 year old Greek ideas)

still with the circles though…

Tycho Brahe's dope observations

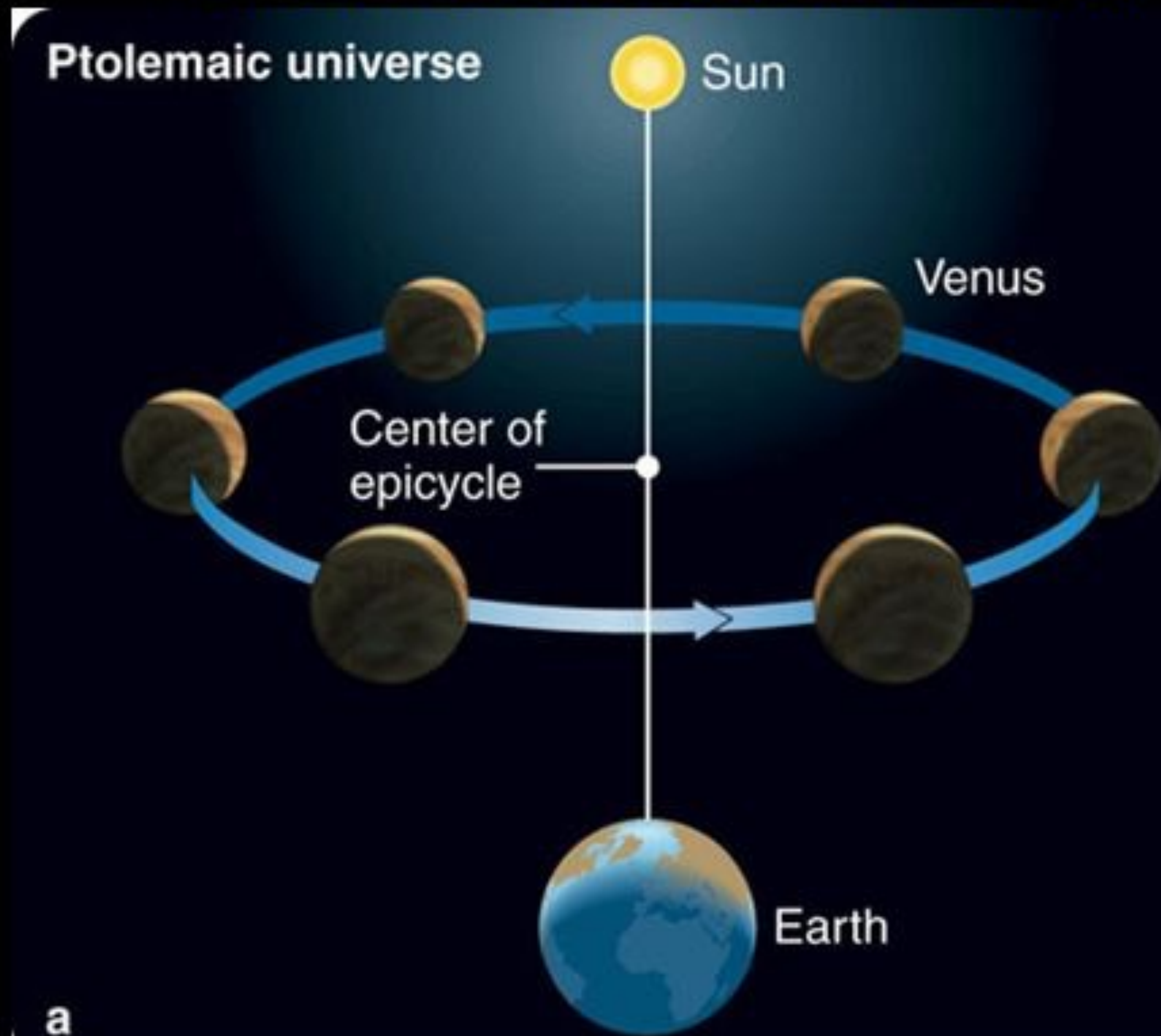Made the best astronomical measurements before the age of the telescope

Failed to measure stellar parallaxes — concluded the Earth must be stationary

Built a hybrid model to reconcile the simpler Copernican idea with a stationary Earth
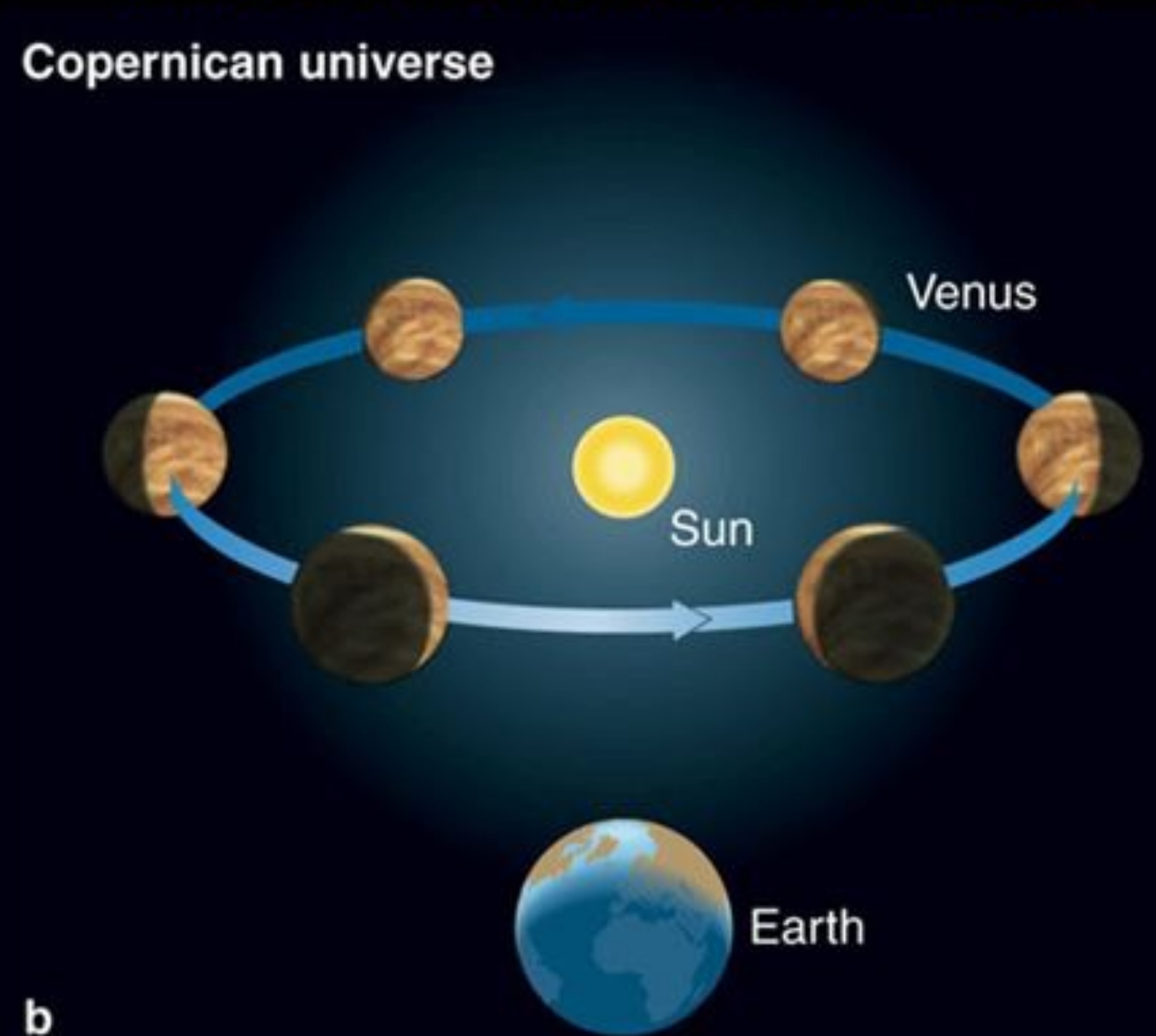
Had a metal nose, died heroically
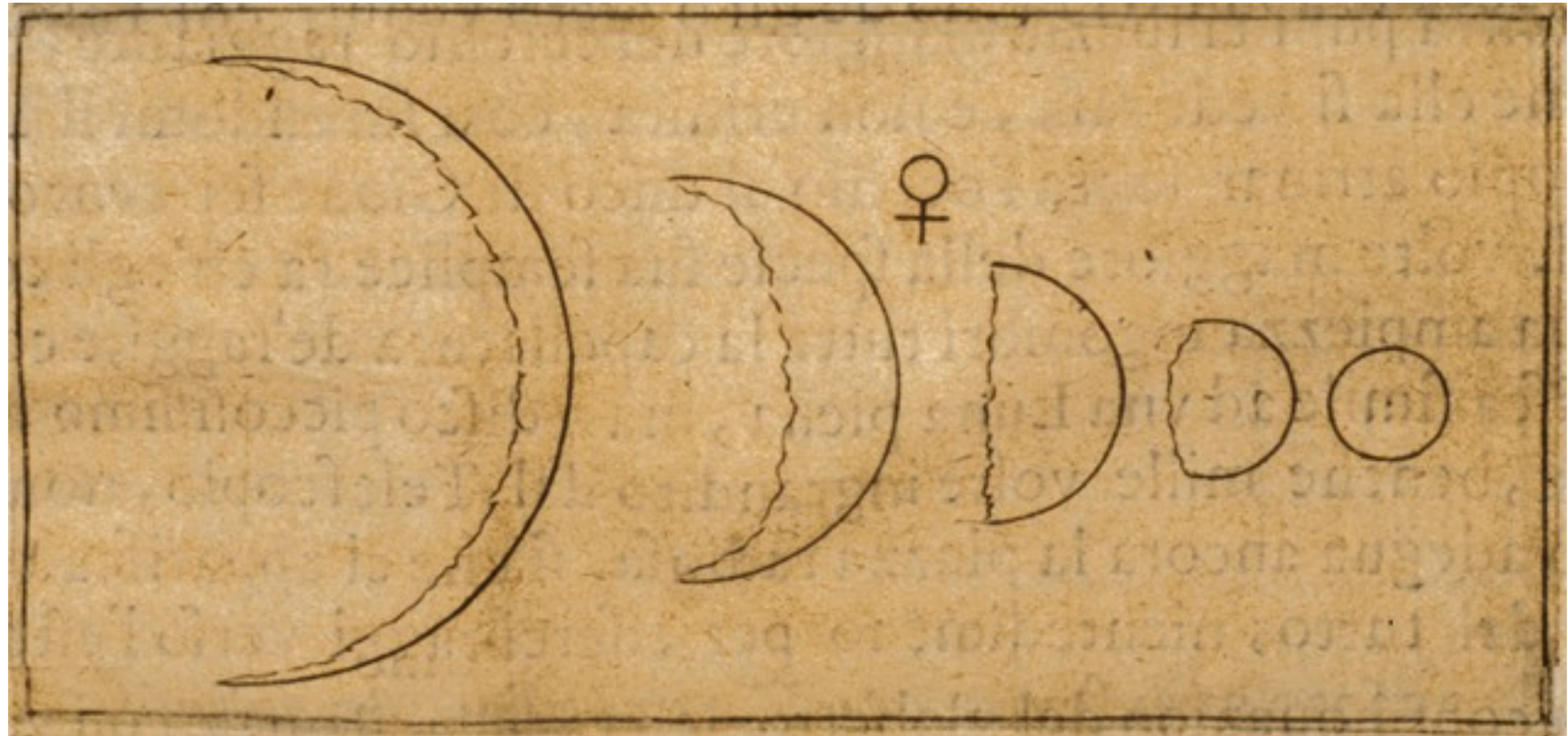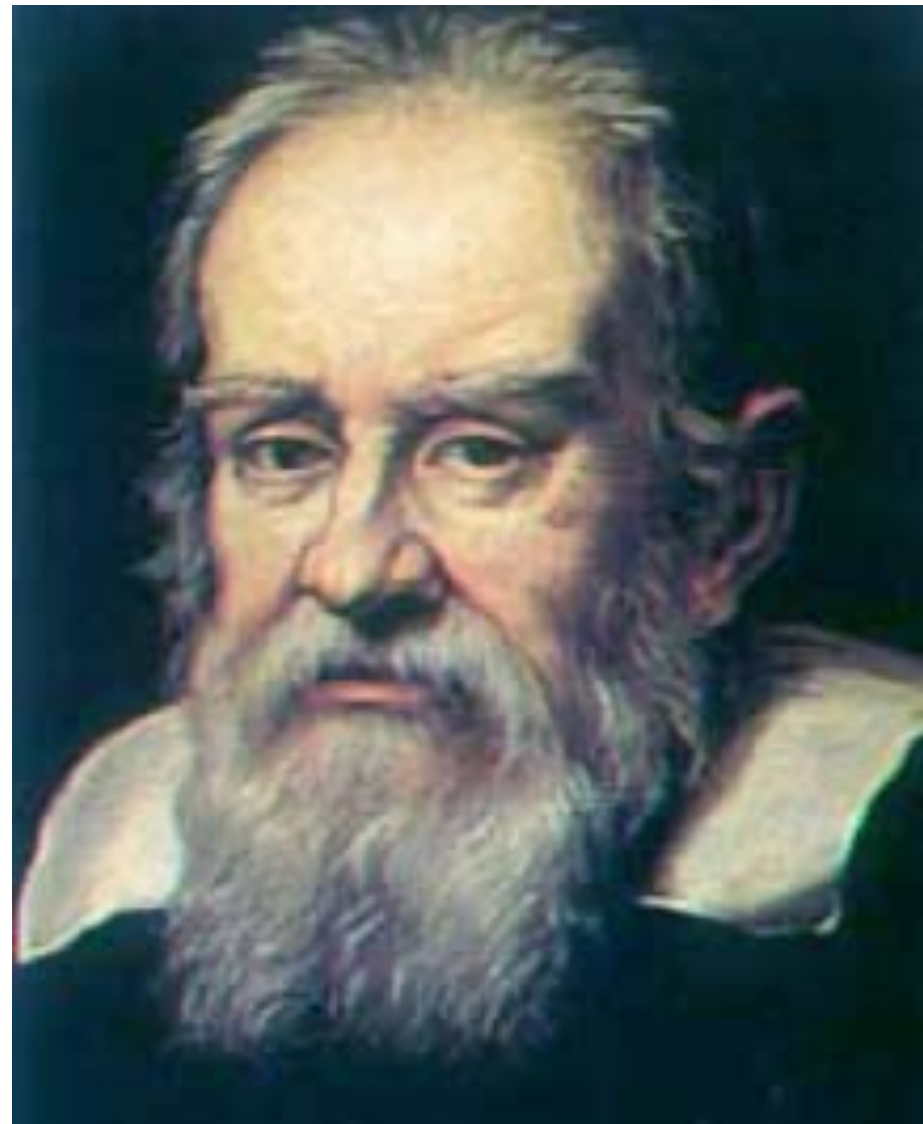
Galileo performs a "crucial experiment"

Galileo's observations of the phases of Venus in 1610
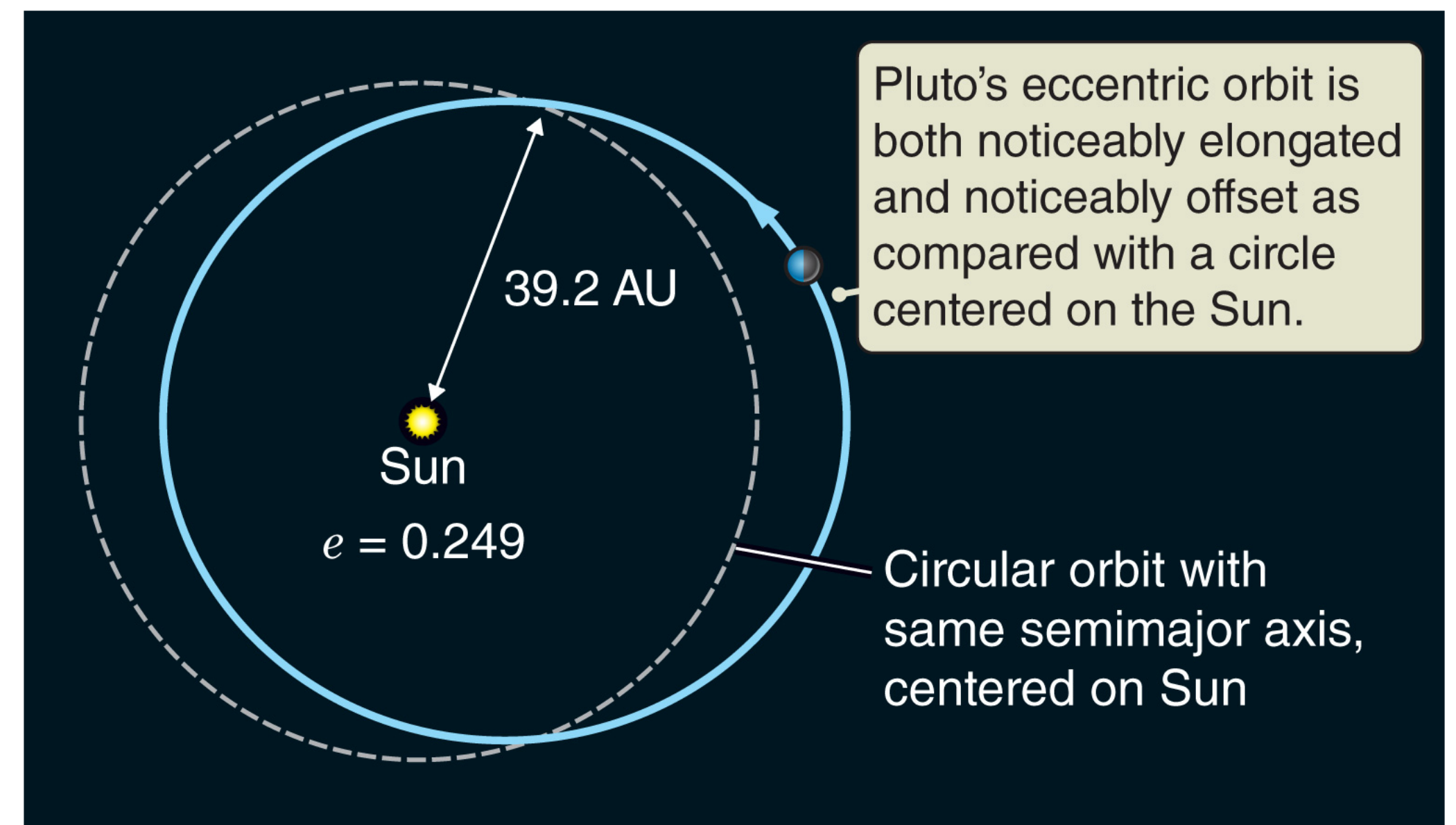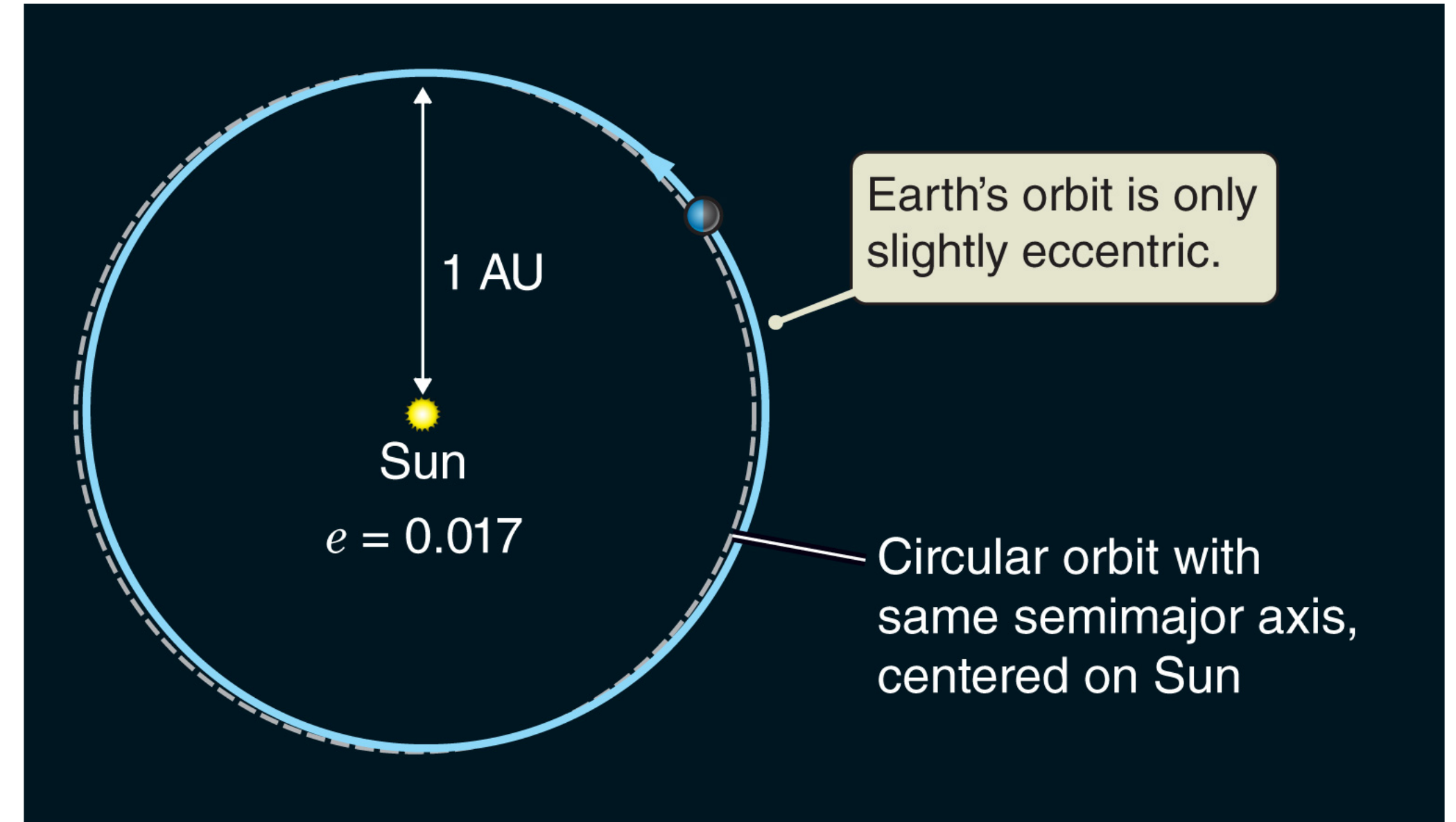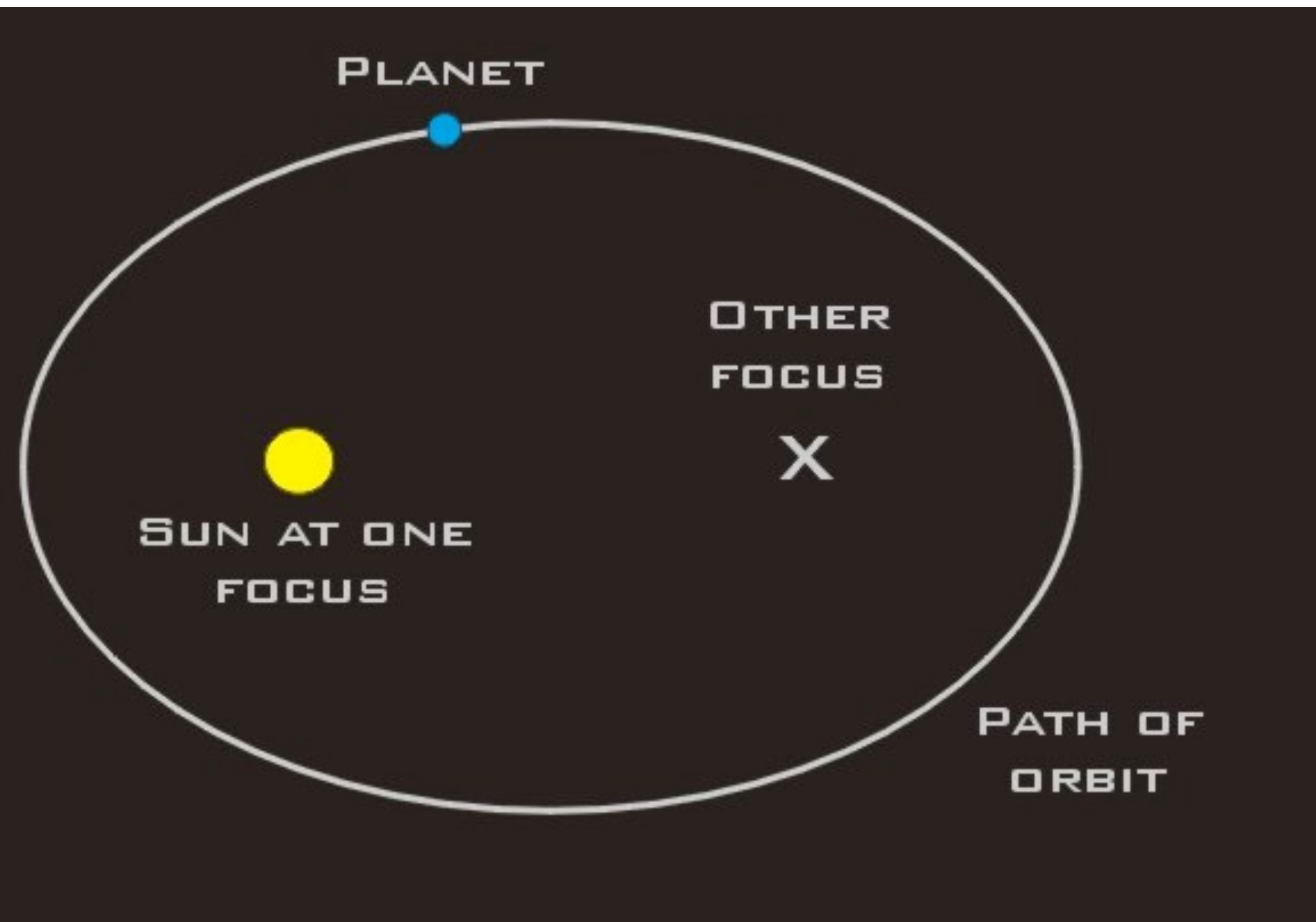
Kepler's Insight
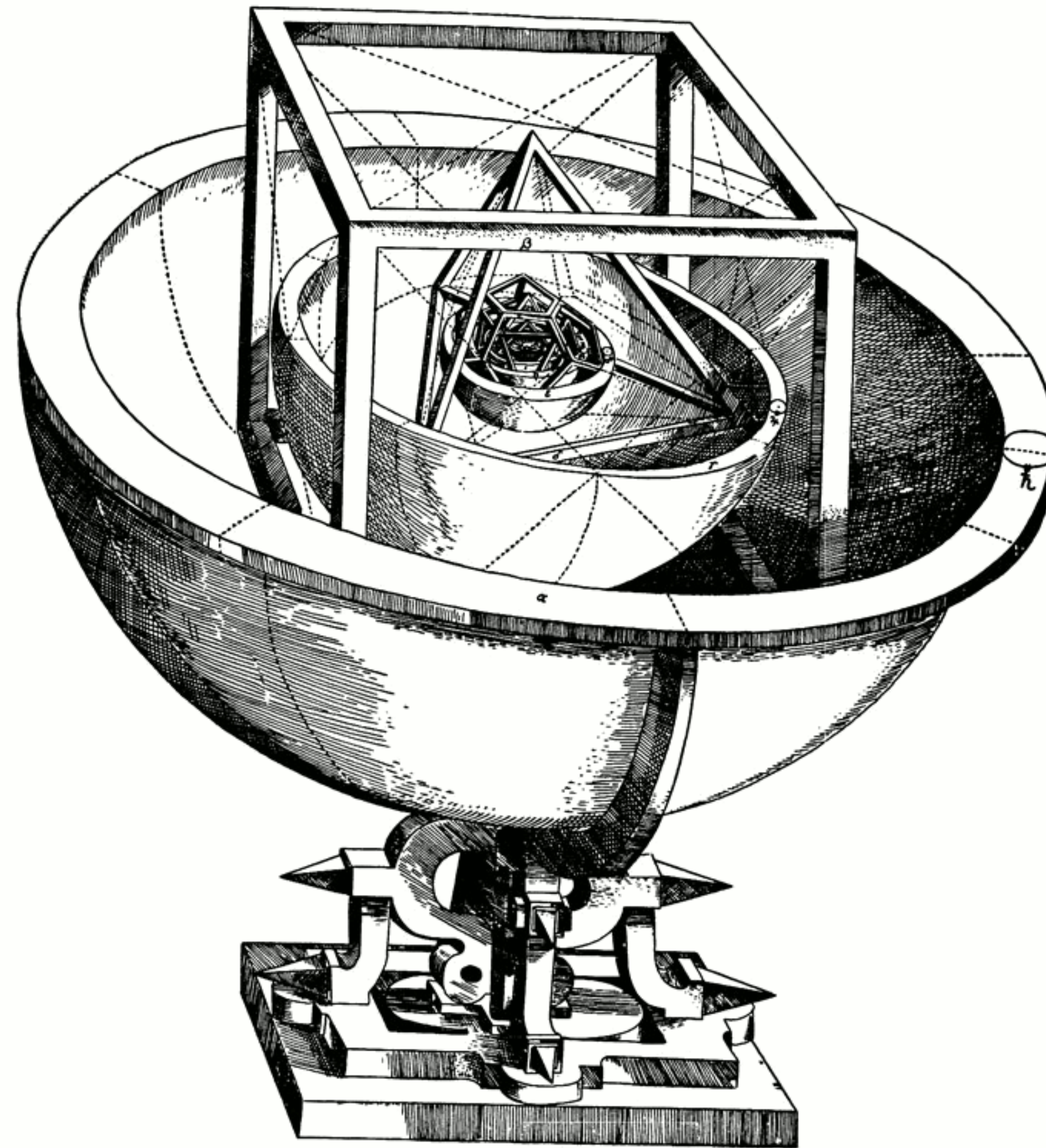
- trusted Tycho's data
- thought Copernicus' Sun-centered model was right
- believed Ptolemy's and Copernicus' assumption that orbits were circular was correct

These assumptions were inconsistent — at least one of them had to be wrong.

Like a good scientist, Kepler trusted the data most and abandoned circles

Kepler's 3 Laws!

1) Planets move around the Sun on elliptical paths, with the Sun at one focus of the ellipse

Earth's orbit is only slightly eccentric.

1 AU

Sun

e = 0.017

Circular orbit with same semimajor axis, centered on Sun

Pluto's eccentric orbit is both noticeably elongated and noticeably offset as compared with a circle centered on the Sun.

39.2 AU

Sun

e = 0.249

Circular orbit with same semimajor axis, centered on Sun

PLANET

OTHER FOCUS

X

SUN AT ONE FOCUS

PATH OF ORBIT

Major Axis

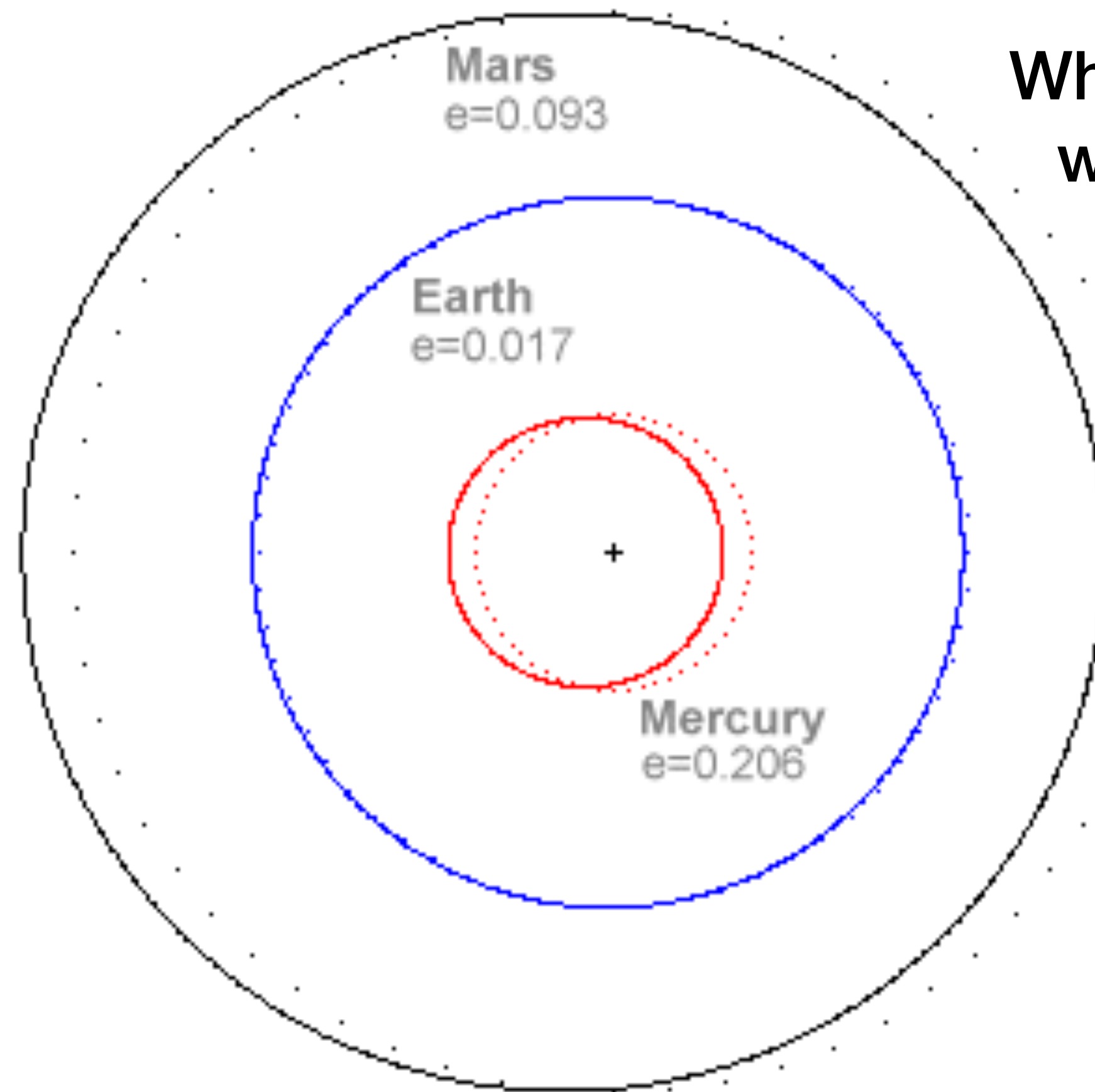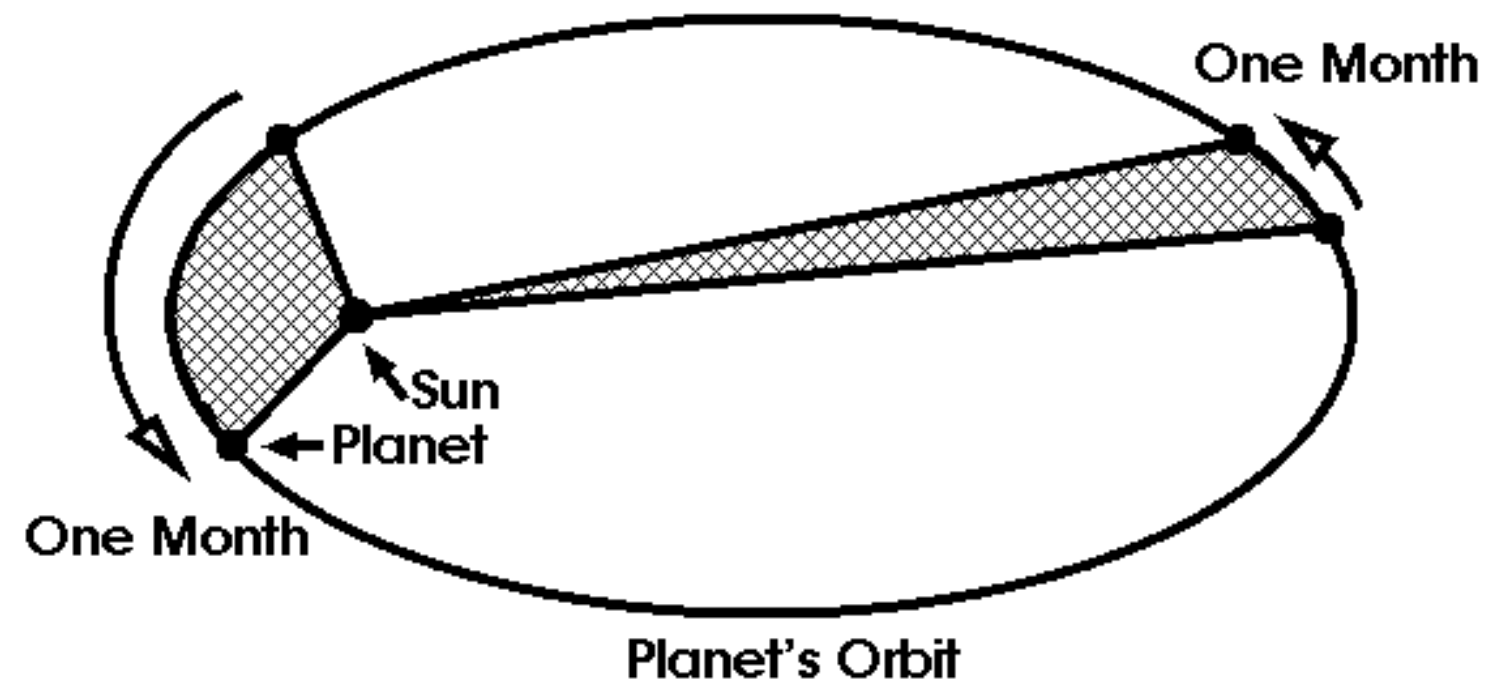ASTR/PHYS 3070: Foundations Astronomy

Kepler's 3 Laws!

2) The area of the ellipse traced out by the motion of the planet in a given period of time is always the same: "equal areas in equal times"
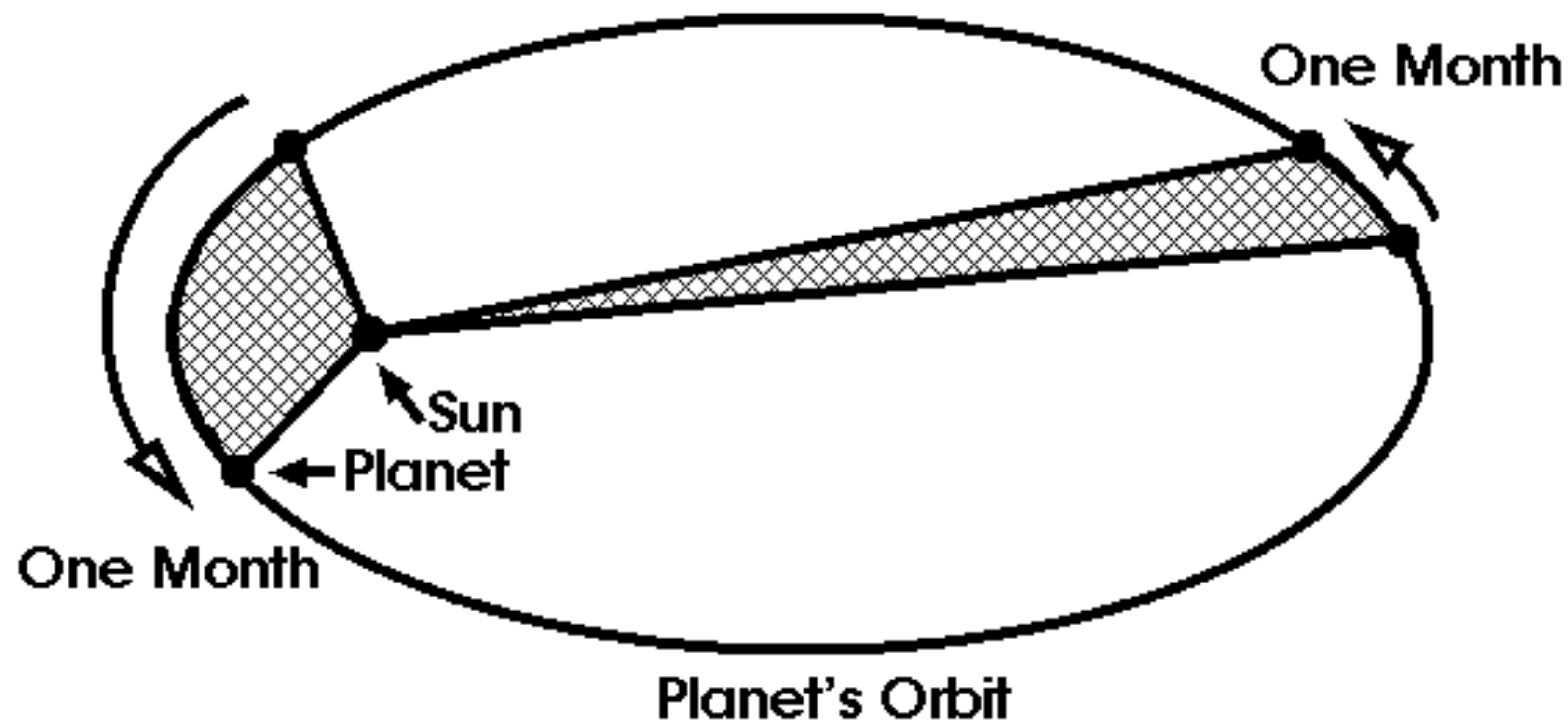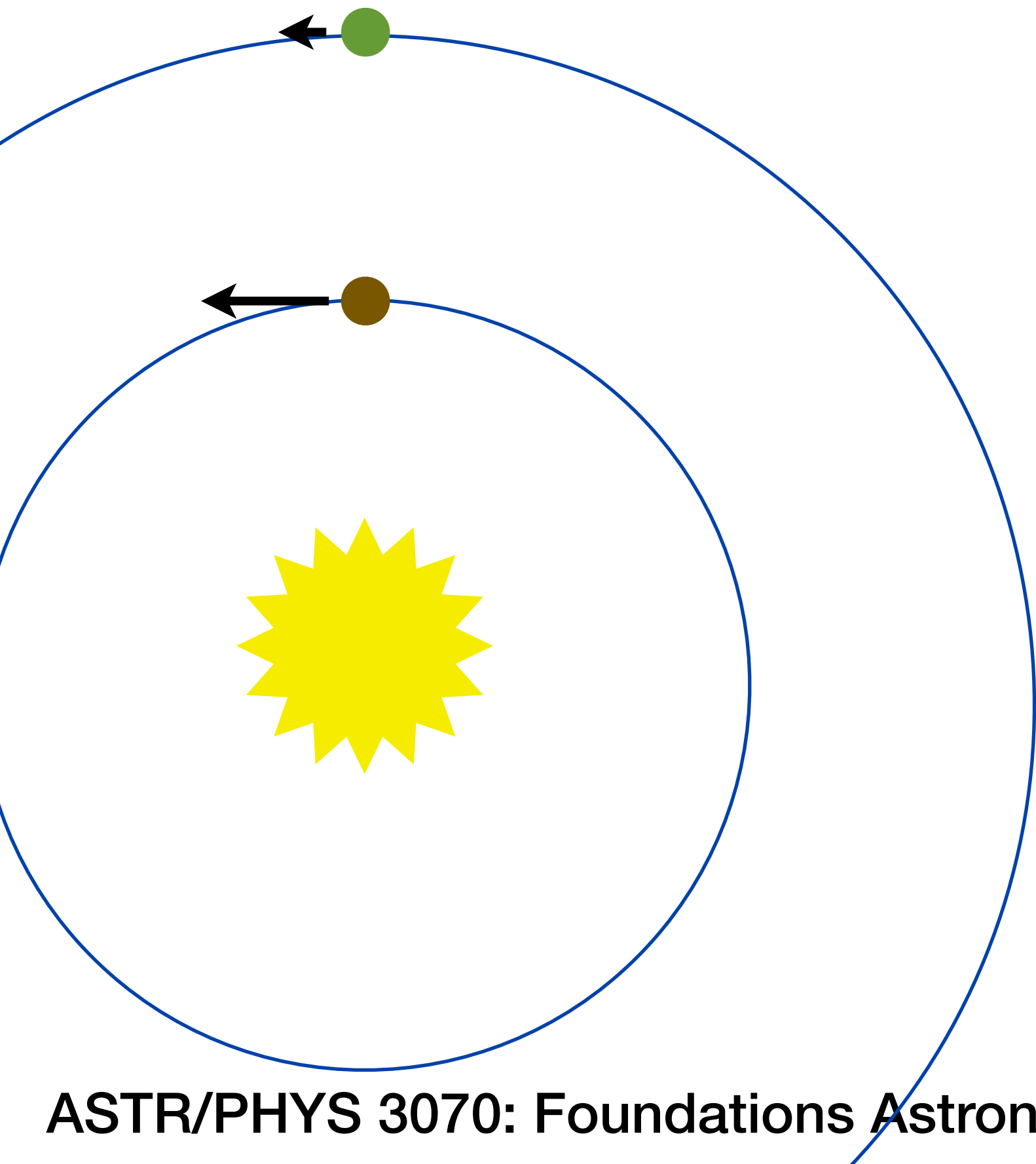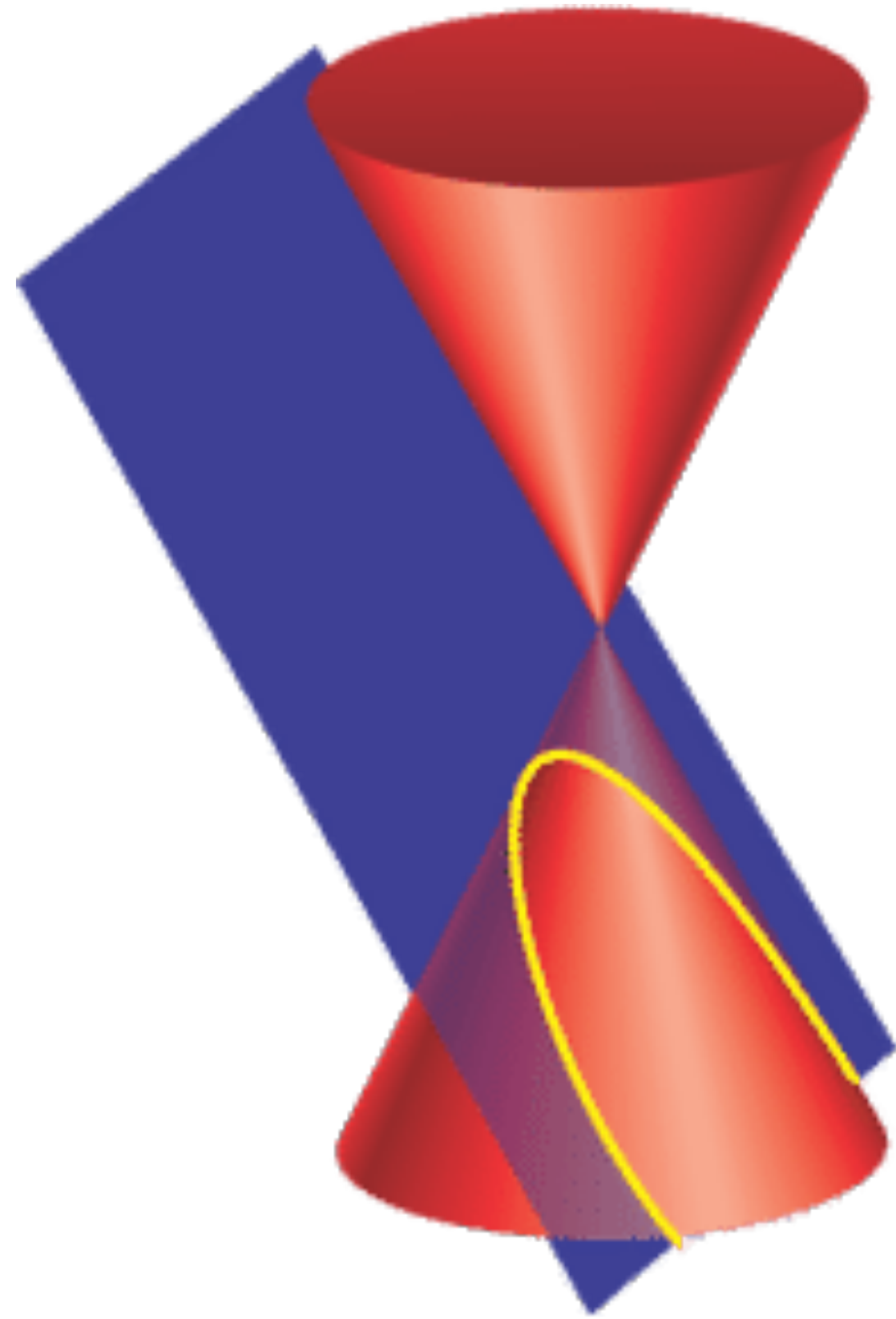
Kepler's 3 Laws!

2) The area of the ellipse traced out by the motion of the planet in a given period of time is always the same: "equal areas in equal times"

Which of the three planets shown would experience the smallest change in orbital speed?

Kepler's 3 Laws

3) The farther from the Sun a planet orbits, the slower it moves (in addition to having farther to travel in order to complete a revolution around the Sun).
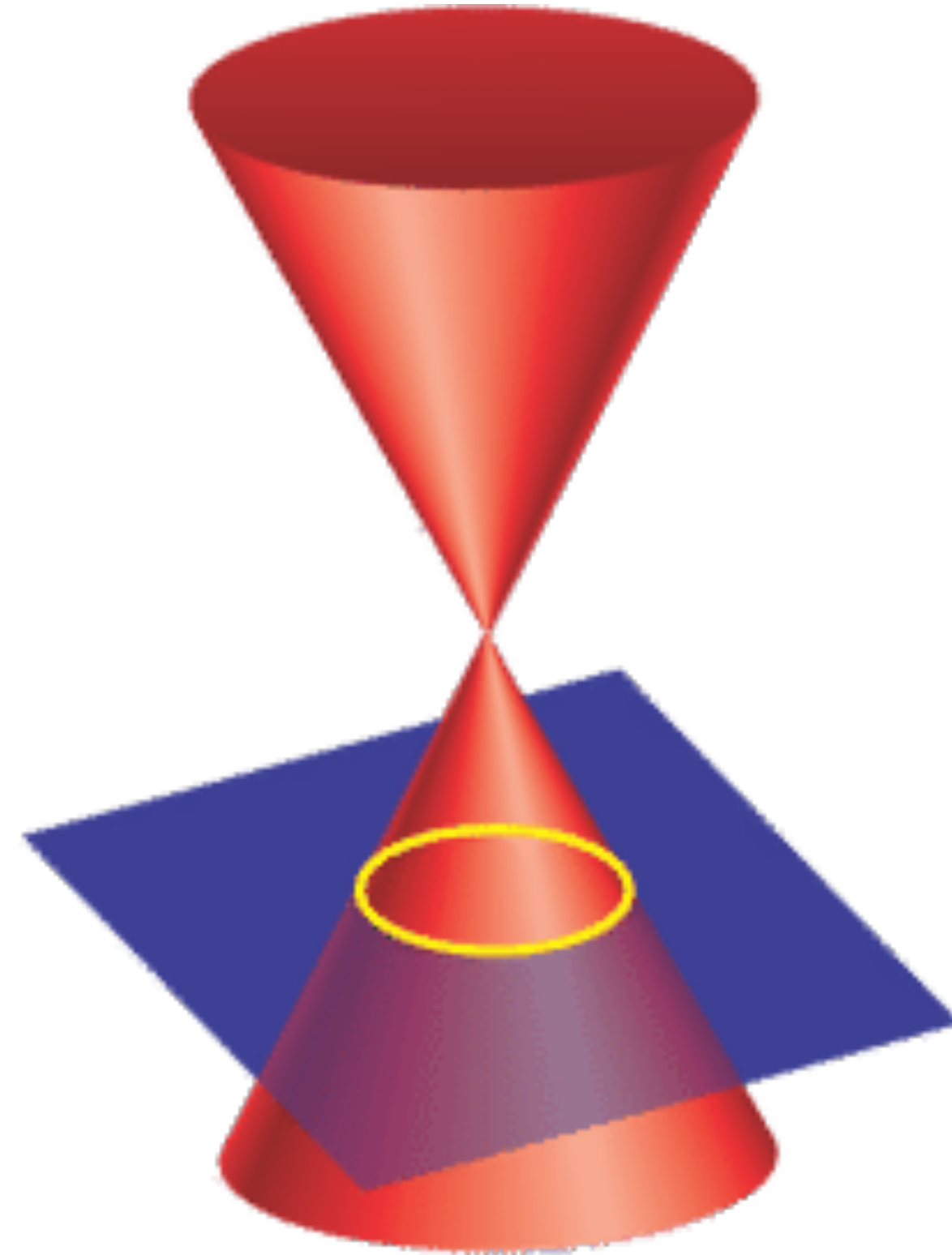
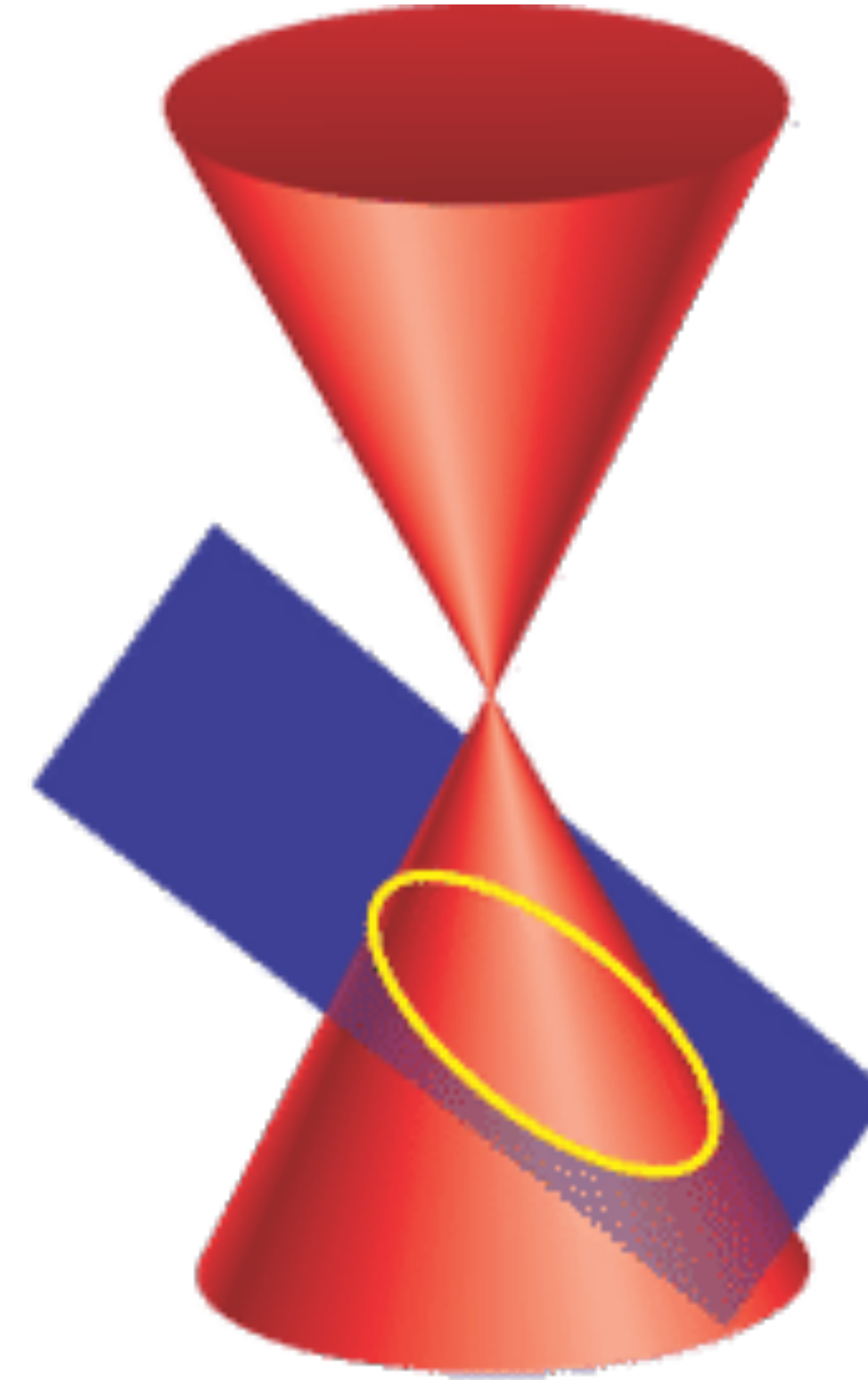# Orbits are Conic Sections

Parabola
$e = 1$
$E_{tot} = 0$

Circle
$e = 0$
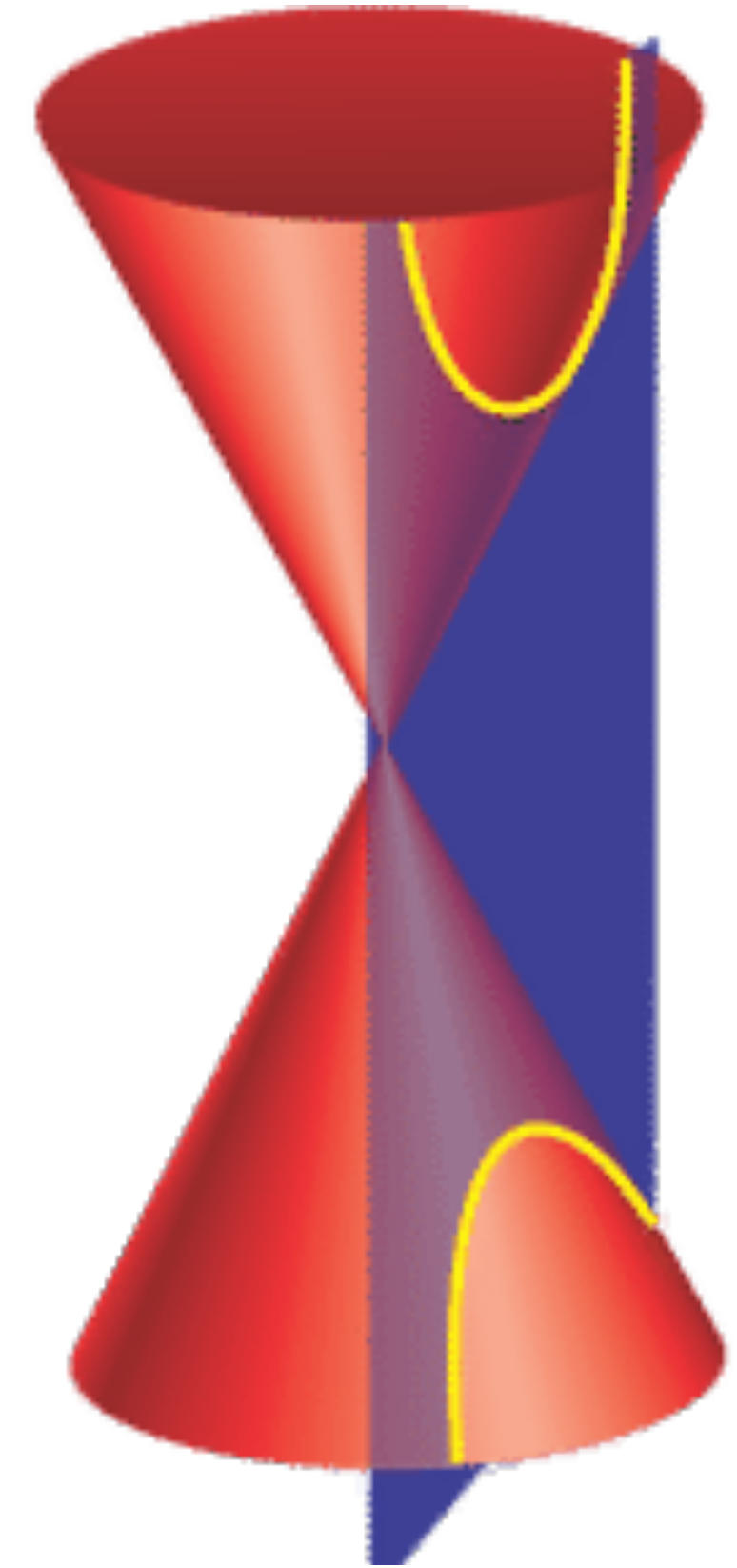$E_{tot} < 0$ (minimum
for a given L)

Ellipse
$0 < e < 1$
$E_{tot} < 0$

Hyperbola
$e > 1$
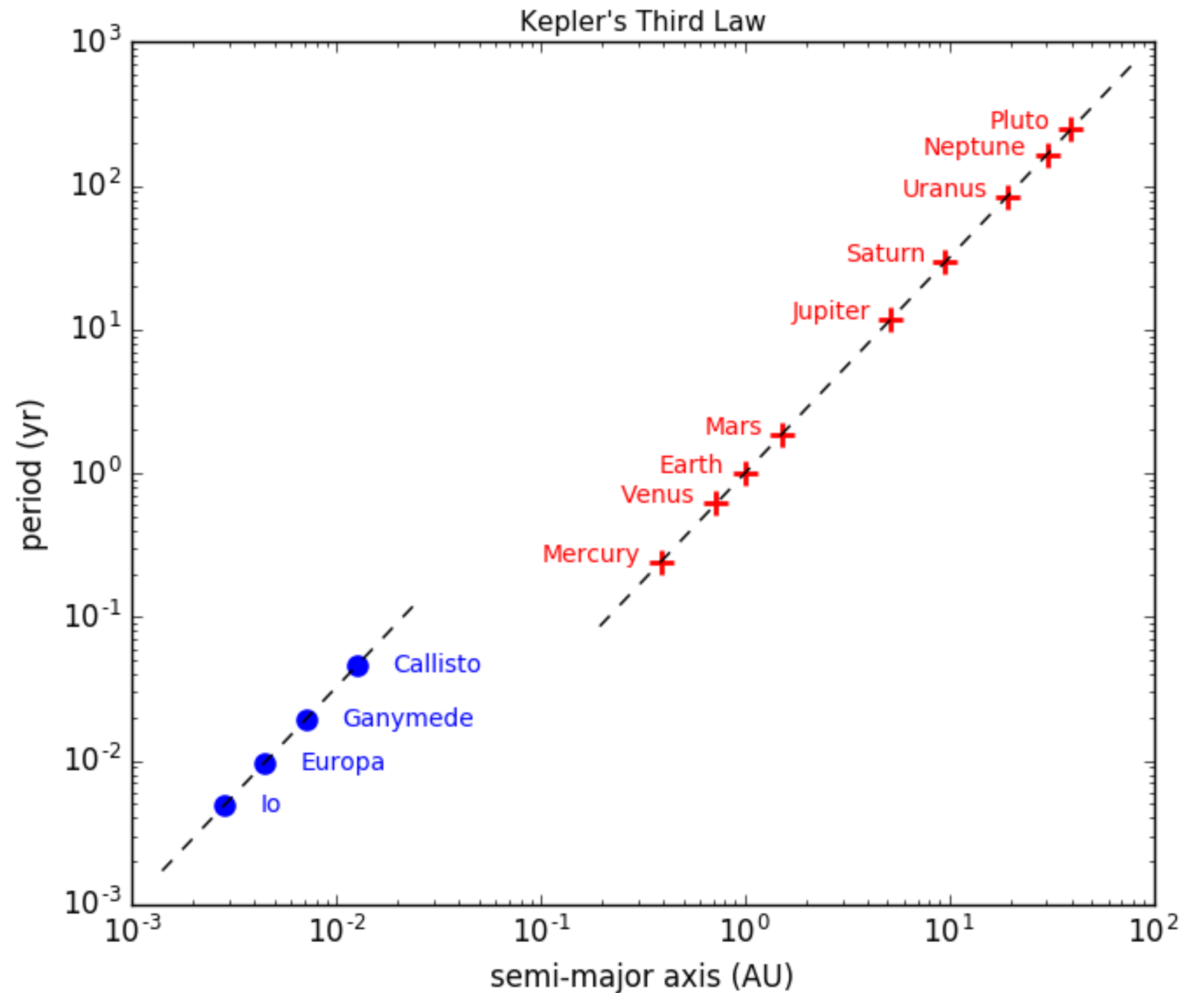$E_{tot} > 0$

Kepler's 3rd Law

Log-log plot
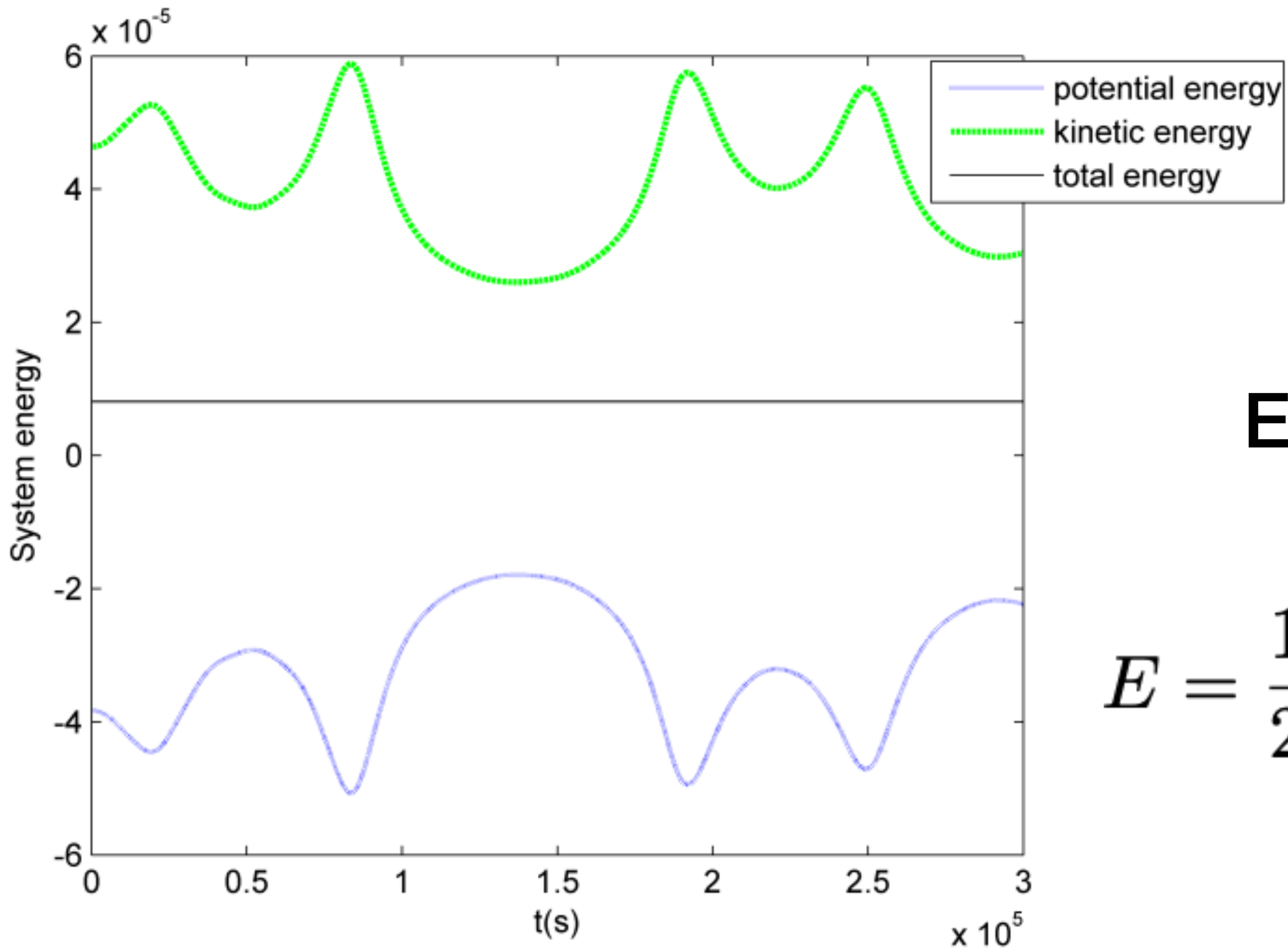Relations to some power
(called power laws) appear
as straight lines

$$y = Ax^p$$

$$\log_{10}(y) = \log_{10}(Ax^p)$$

$$= \log_{10} A + p \log_{10} x$$
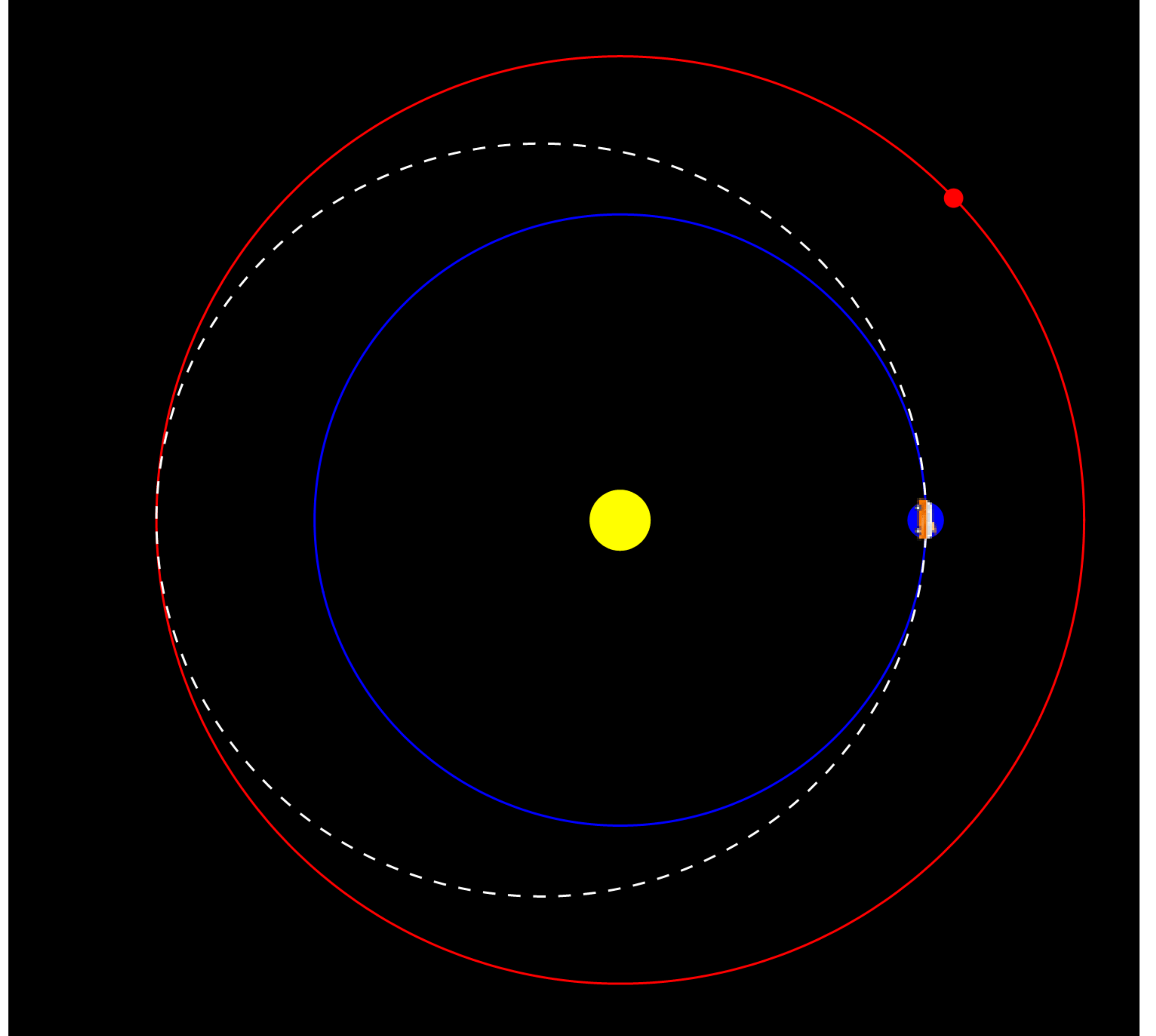
$$y' = B + Cx'$$

Kepler's Third Law

Orbital Energetics

$$E = \frac{1}{2}mv^2 - \frac{GMm}{r}$$

Hohmann Transfer Orbit

Virial Theorem

$$2 \langle K \rangle = - \langle U \rangle$$