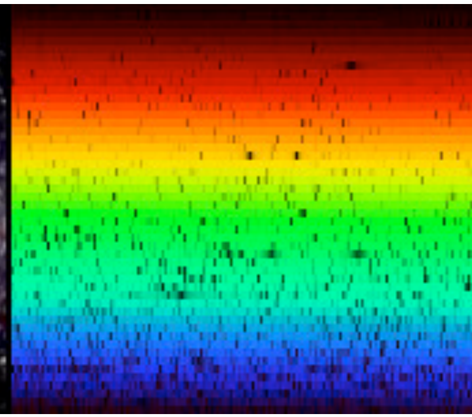
ASTR/PHYS 3070: Foundations Astronomy



Week 2 Tuesday

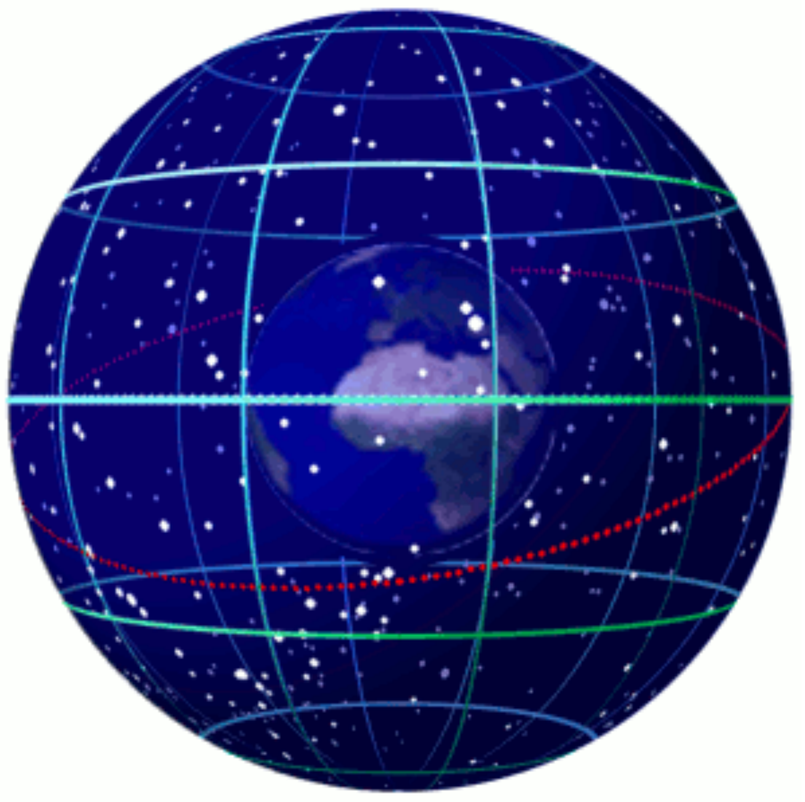
Today's Agenda

- Changes in the Sky
- Greek Scientific Thought
- The Earth Moves!
- Astronomy becomes science and changes the universe

Announcements / Reminders

- Read Chapters 2.4-2.6 & 3 for this week
  - Scanned PDF available on website
  - Inclusive Access eBook accessible
- HW 1 due September 3rd at 11:59pm via Canvas upload

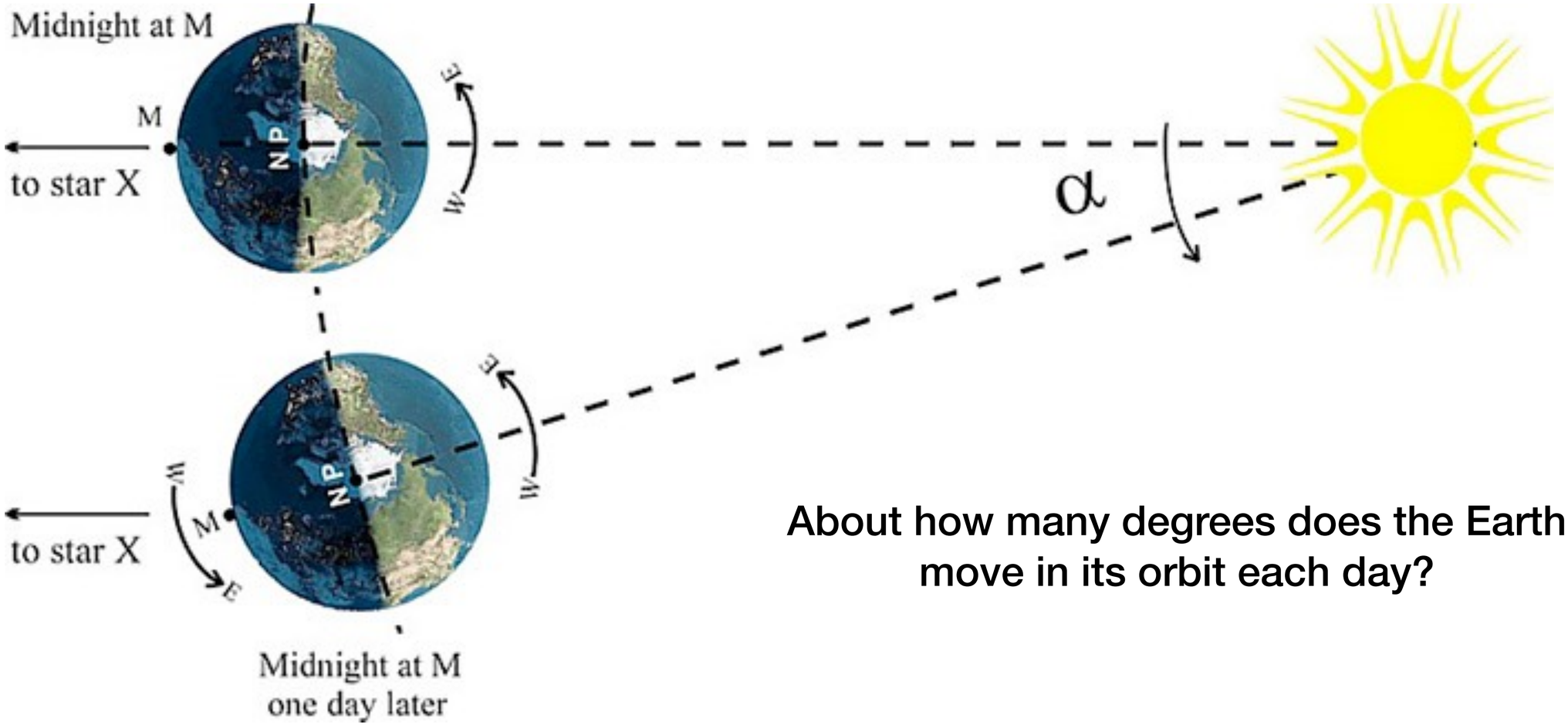
The Night Sky & Astronomical Coordinates



Star trails over the Gemini South telescope

Changes in the Sky

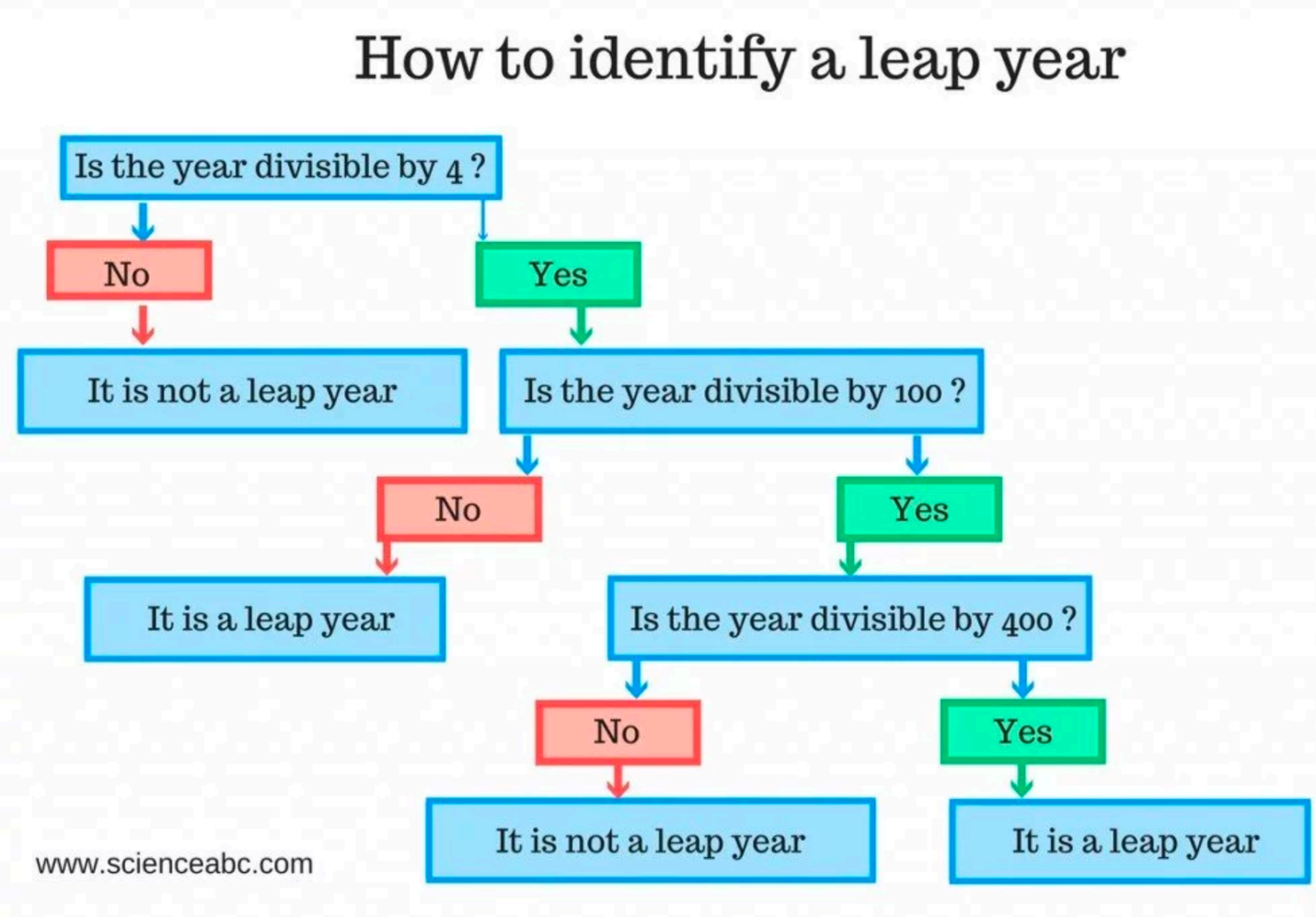
Why star rise/set times change



About how many degrees does the Earth move in its orbit each day?

How many days are there in a year?

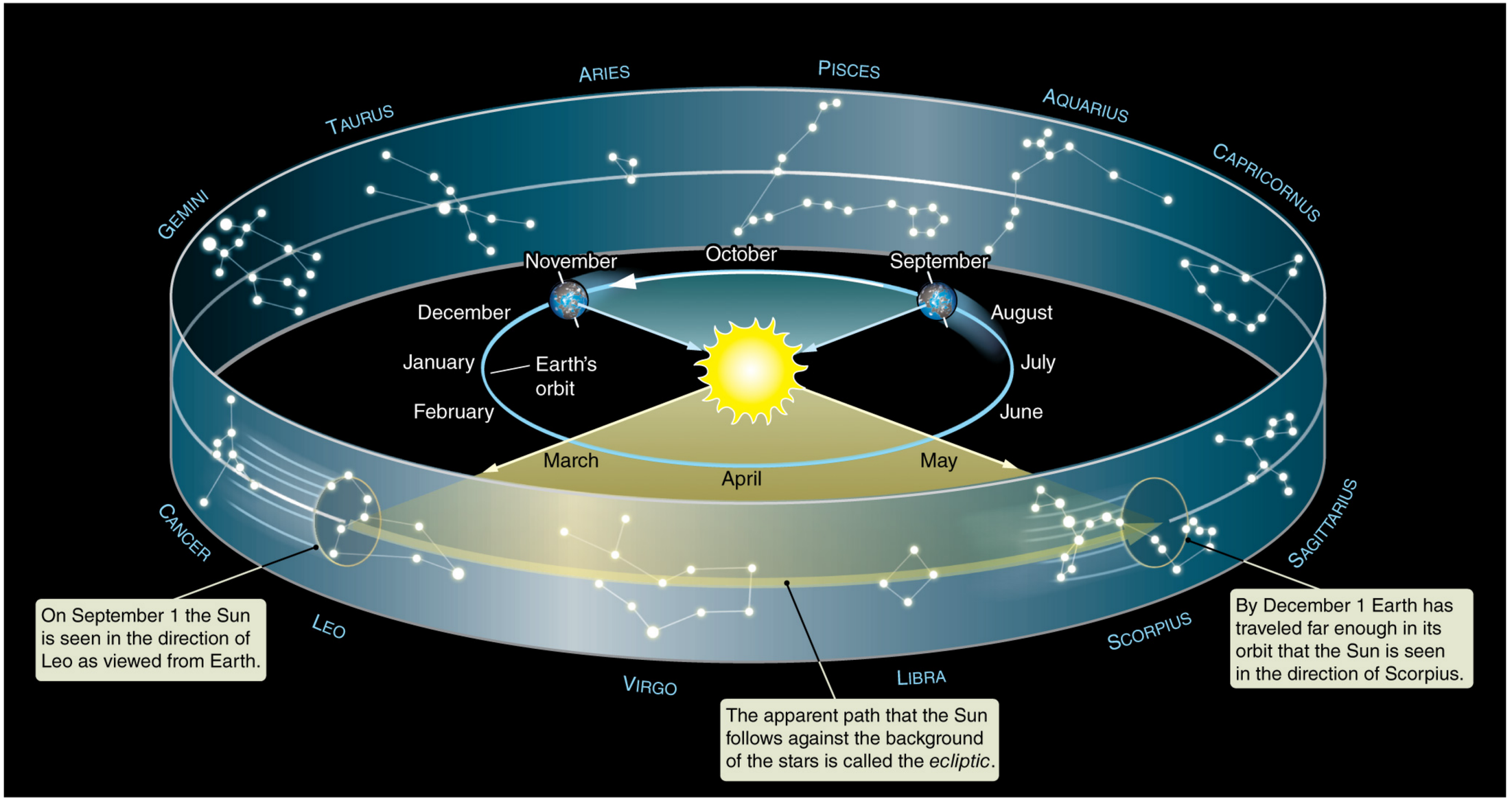
Calendars aren't trivial, because an orbit around the Sun takes 365.2422 days



Julian calendar was used for over 1000 years (leap day every 4 years). Every 400 years, the calendar is offset from the seasons by 3 more days.

Gregorian Calendar (what we use today)

The Ecliptic: Sun's path on the Celestial Sphere



The Ecliptic

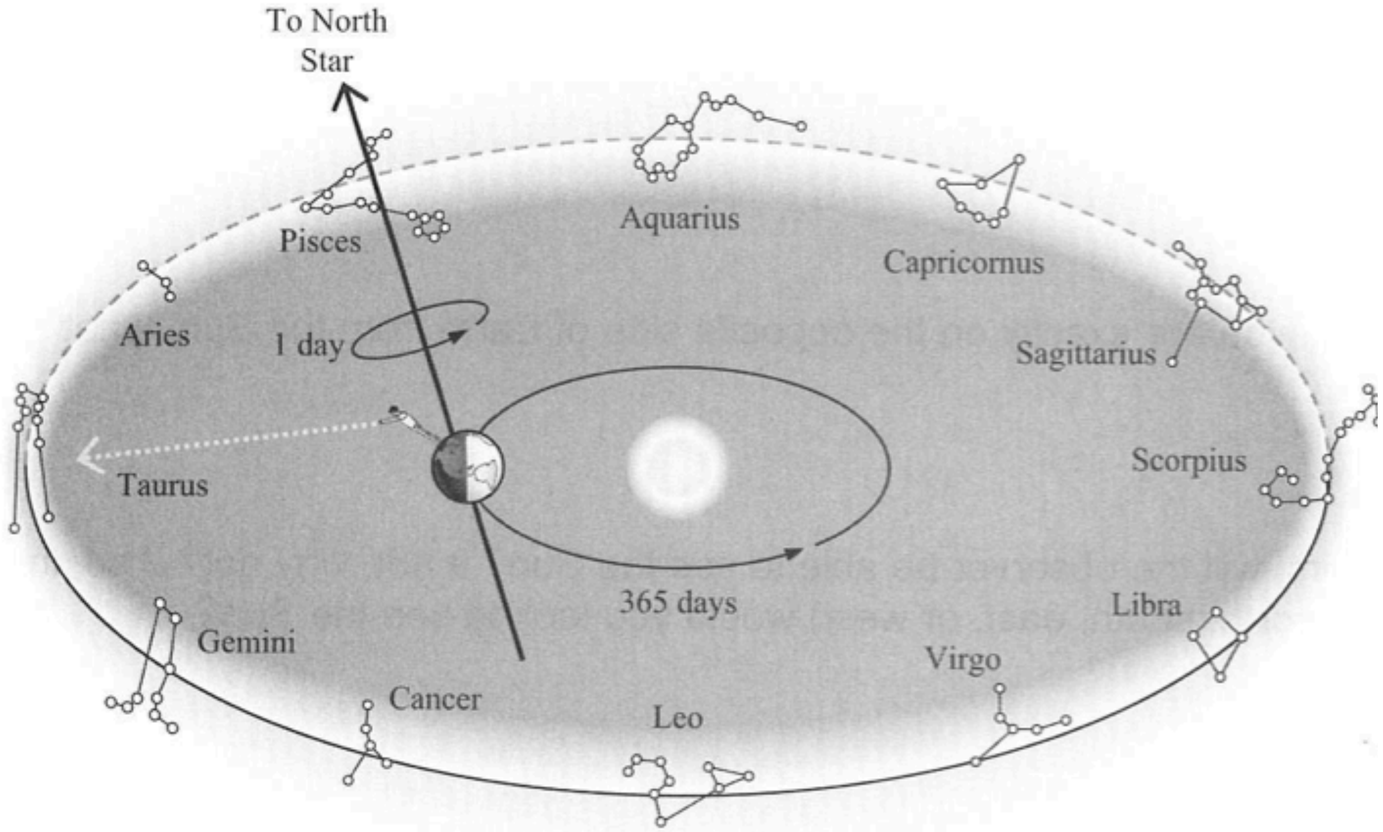


Figure 1

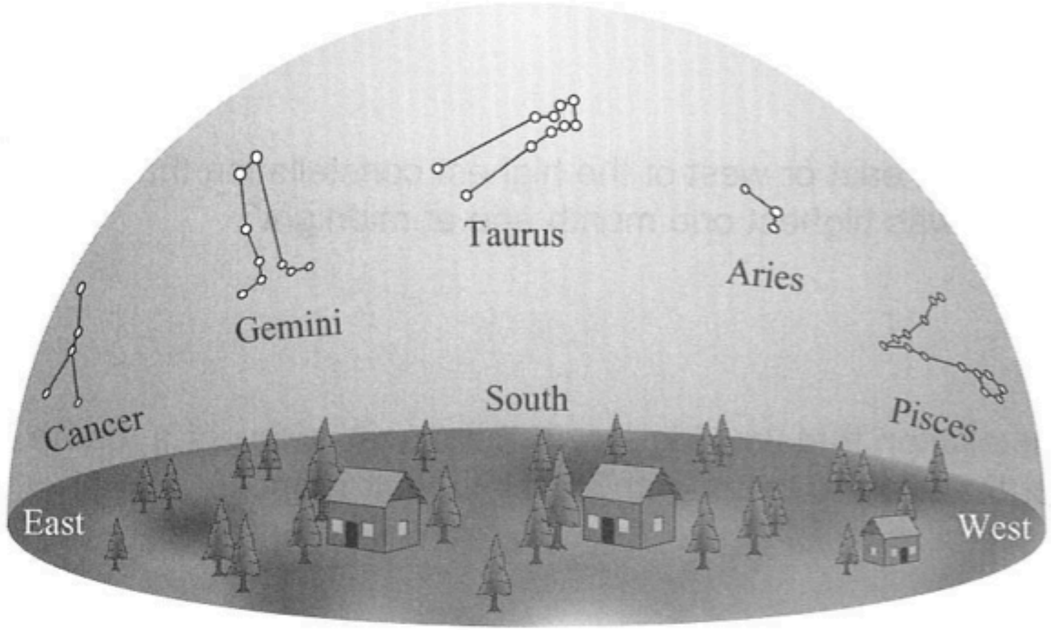
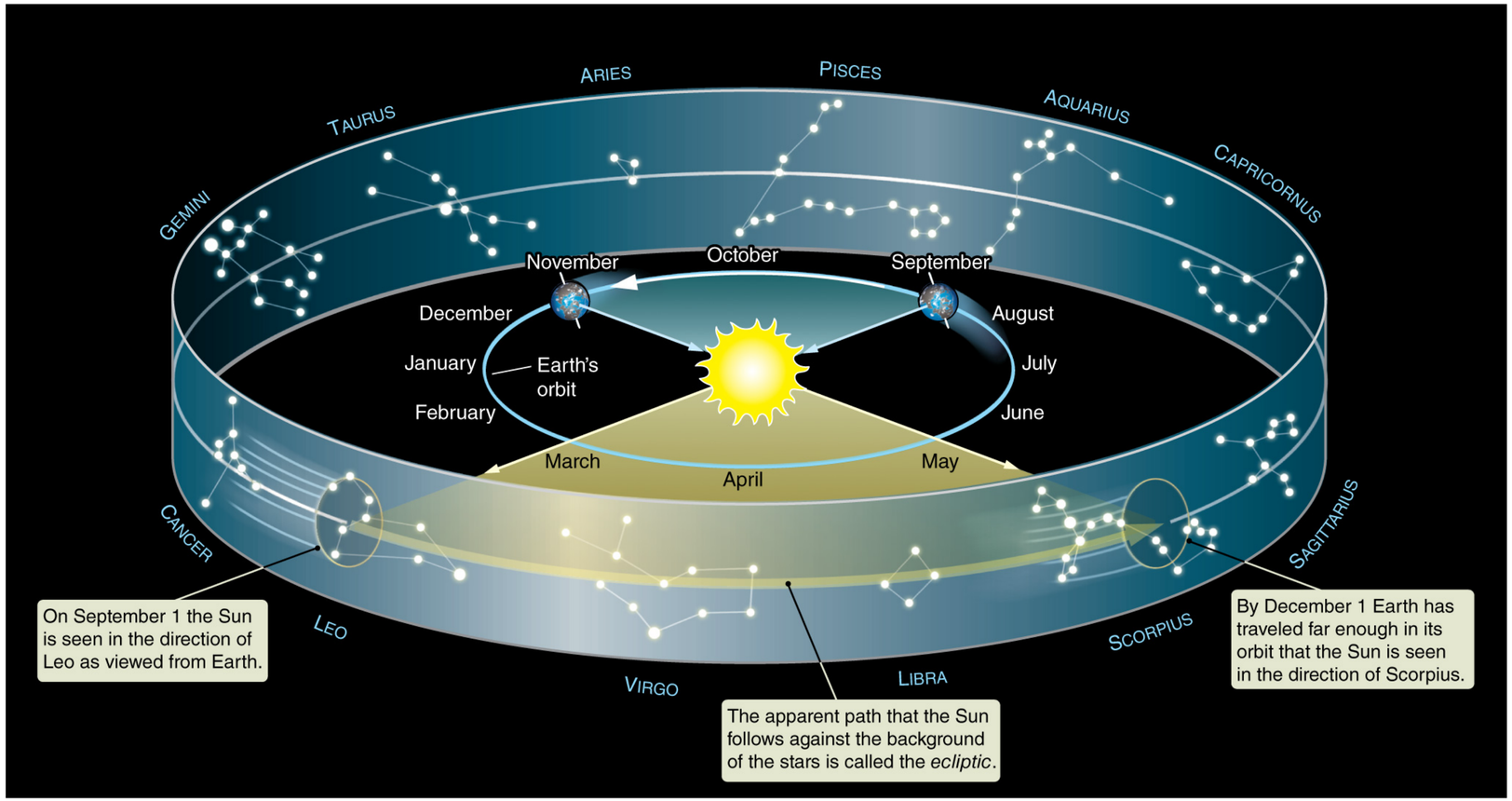


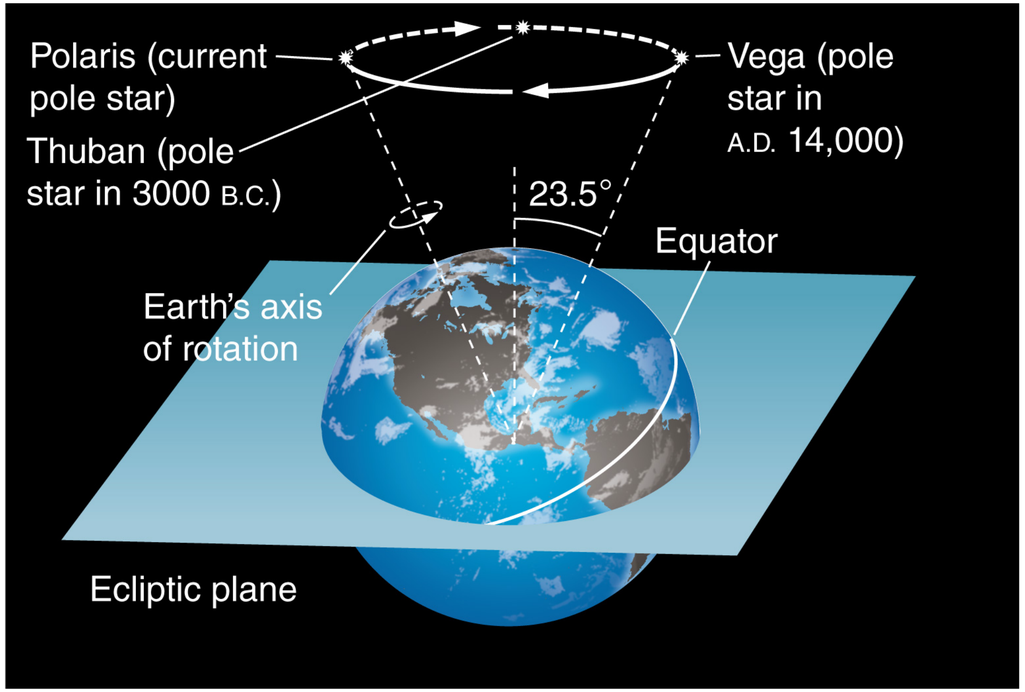
Figure 2

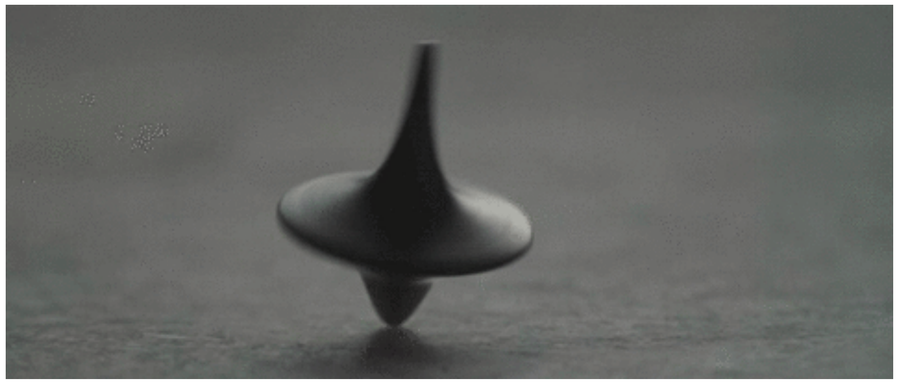
Hey you, what's your sign?

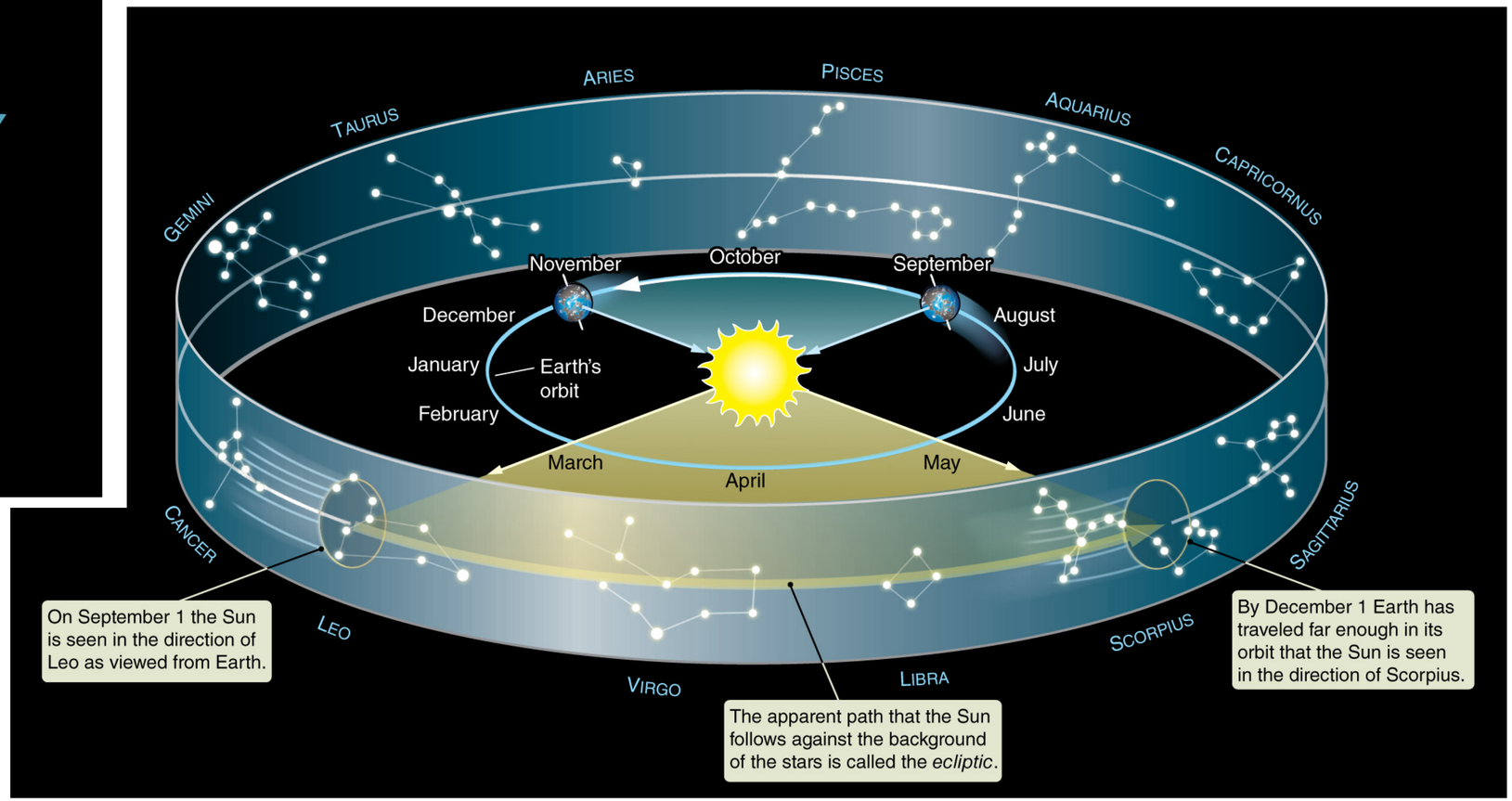
Astrology is bunk!



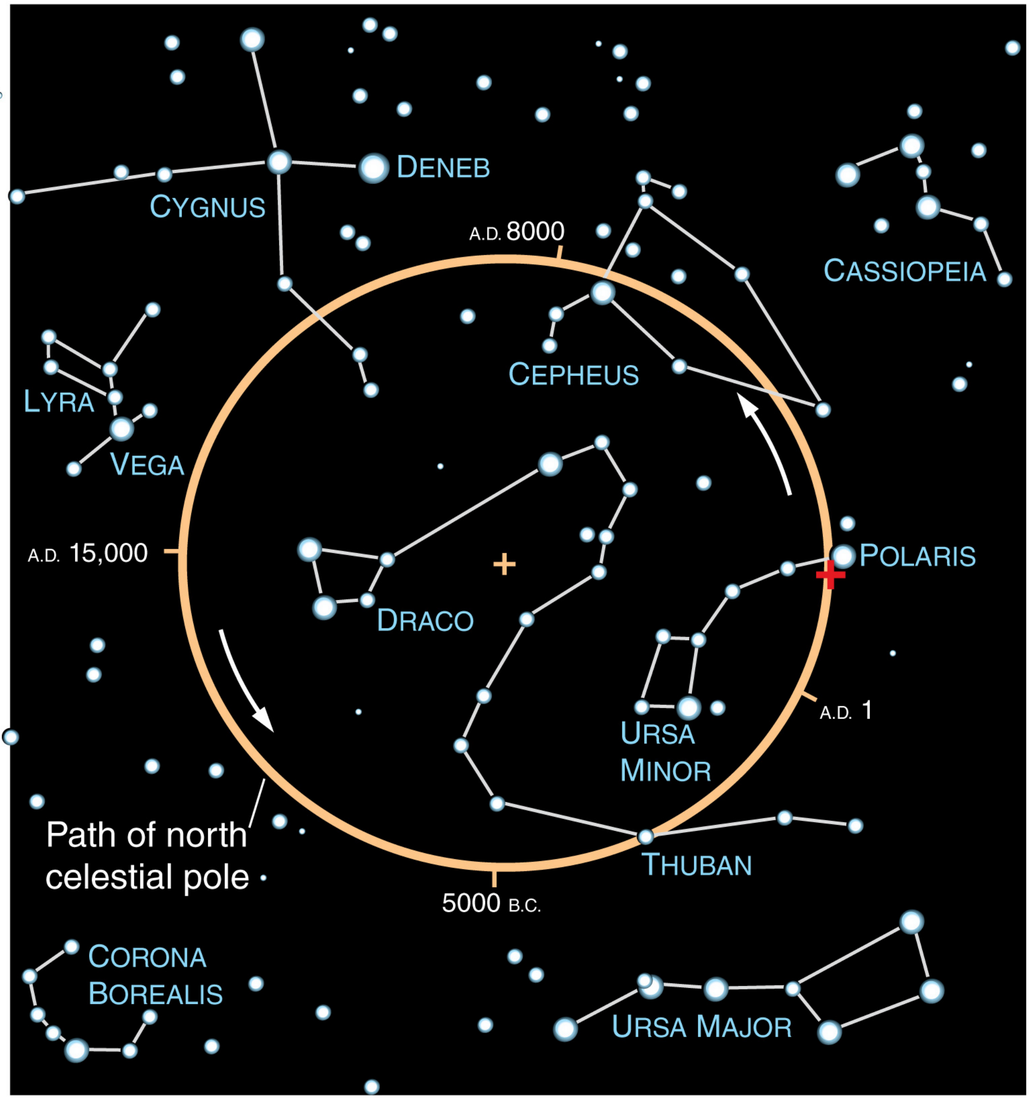
Earth's axis wobbles like a top: called Precession

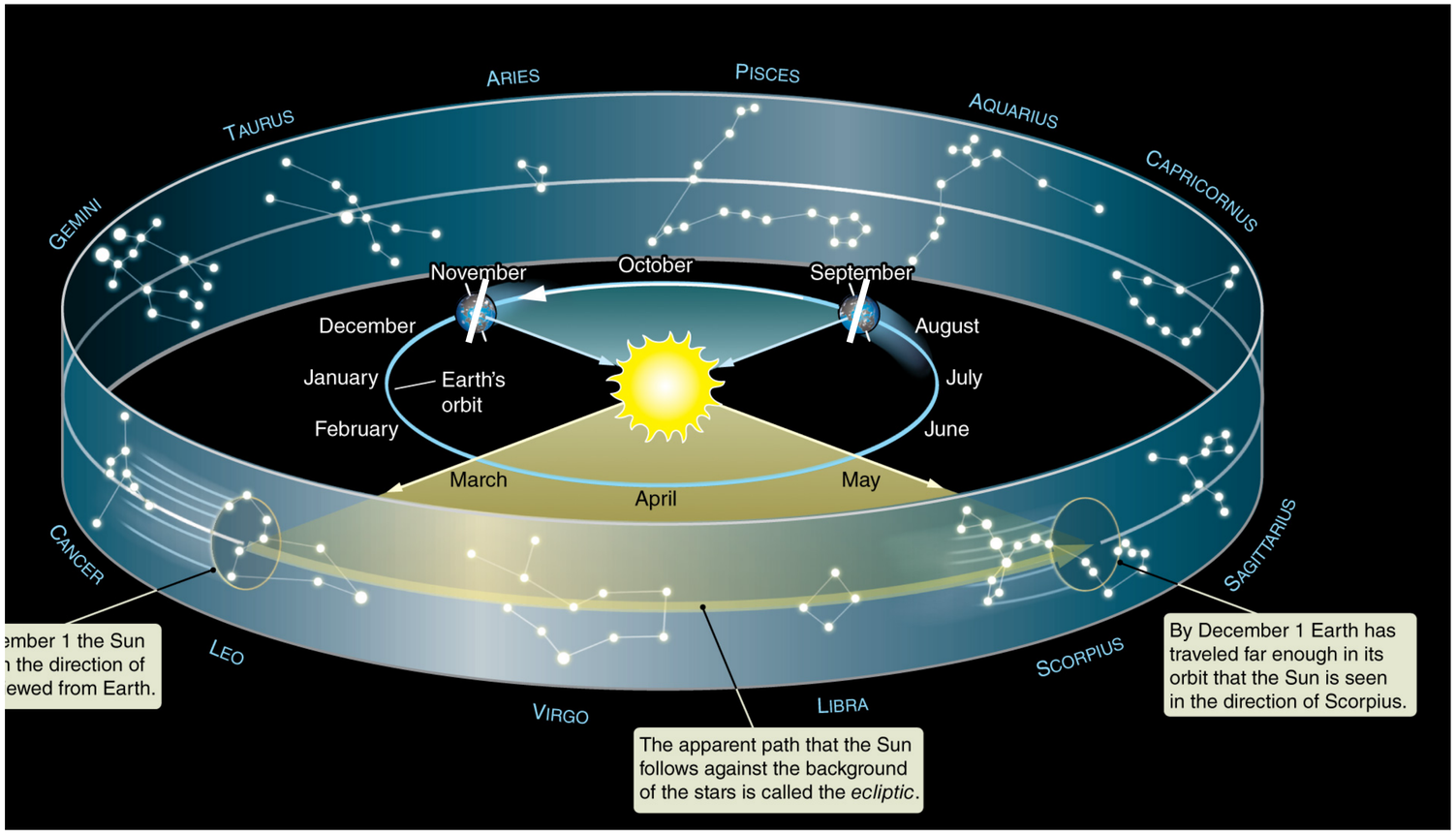






Earth's axis wobbles like a top: called Precession





Because of precession, the RA & Dec of a star are always changing!

To keep sane, astronomers use coordinates from a particular time, referred to as the Epoch; at present, we use Epoch J2000, the RA/Dec objects had at midnight on January 1st, 2000.

To actually locate a star or object when observing, the coordinates must be “precessed”.

This “precession of the equinoxes” has a rate of ~50” per year (modest optical telescopes tend to have angular resolutions of ~1” and fields of view of a few arcminutes across, so this rate is quite significant!

What causes precession (i.e., how is Earth's angular momentum able to change)?

What causes seasons?
What effects result from this cause that leads to colder/hotter temperatures?

Origin of Astronomy

Until Galileo, all astronomy "naked eye"

Tycho Brahe (late 1500s)

<u>Birth of Agriculture</u> ~10,000 years ago
Determine Planting/Harvest Times
(weather can be unreliable)

Therefore astronomy often called the oldest "science"
(observations led to predictions)

Measurements essentially all positional, attempting to predict the paths of planets in the sky for astrological and cosmological reasons

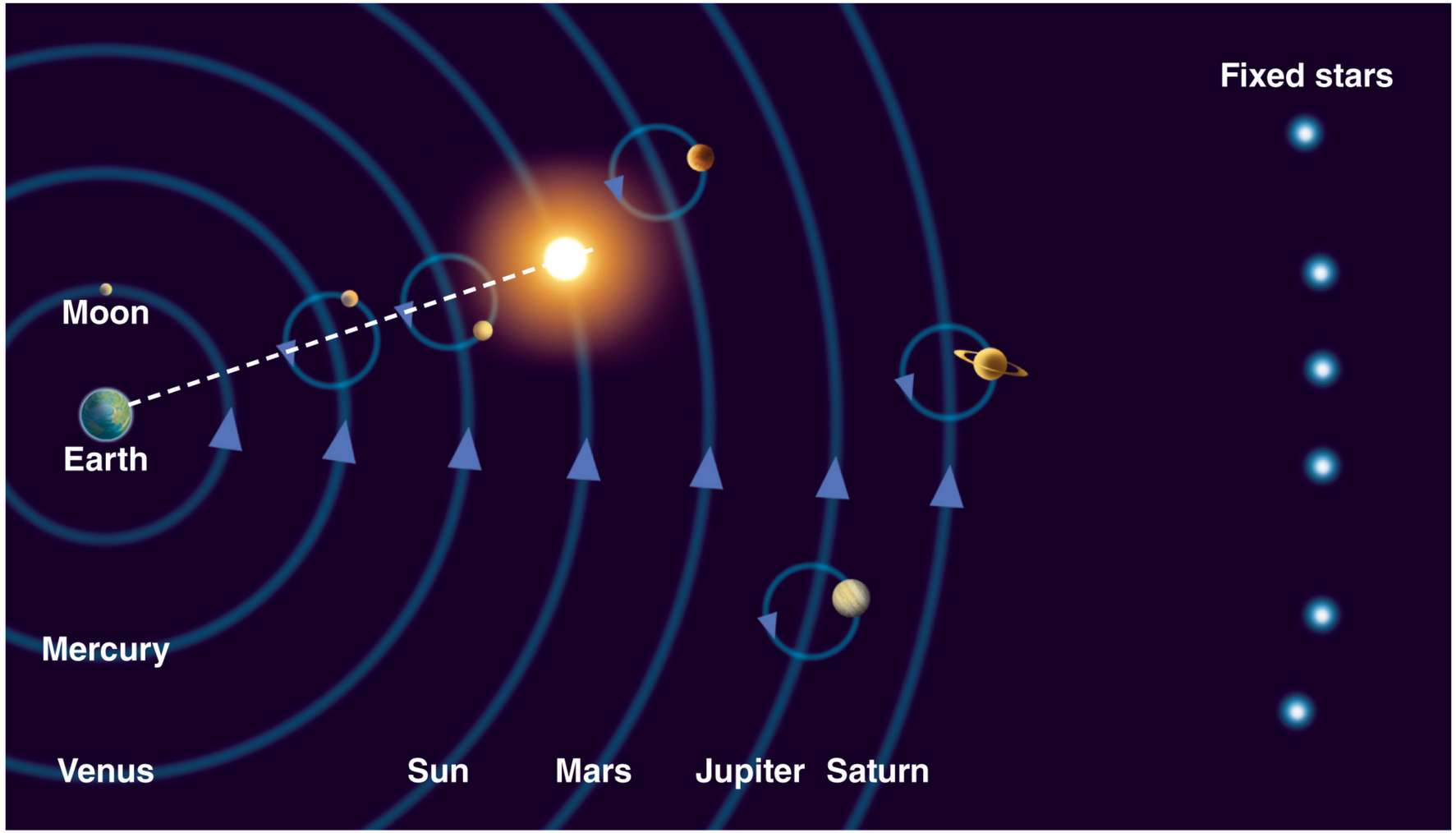
Goal: predict the motions of the planets against the “fixed stars”

Motion was not simple

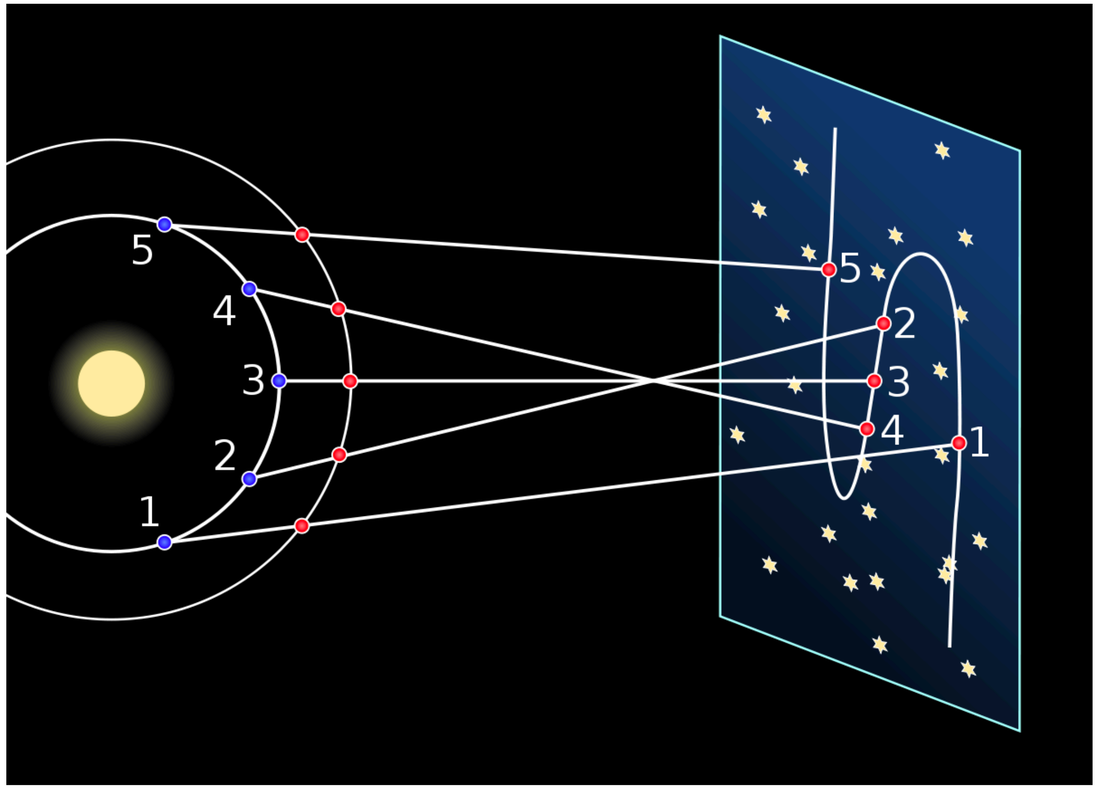
Models were built to explain them, and did OK — but discrepancies remained

The lack of perfect agreement implied the “true” description of planetary motion was still up for grabs

The celestial sphere was perfect and unchanging, so motion must be circular, the perfectest of shapes



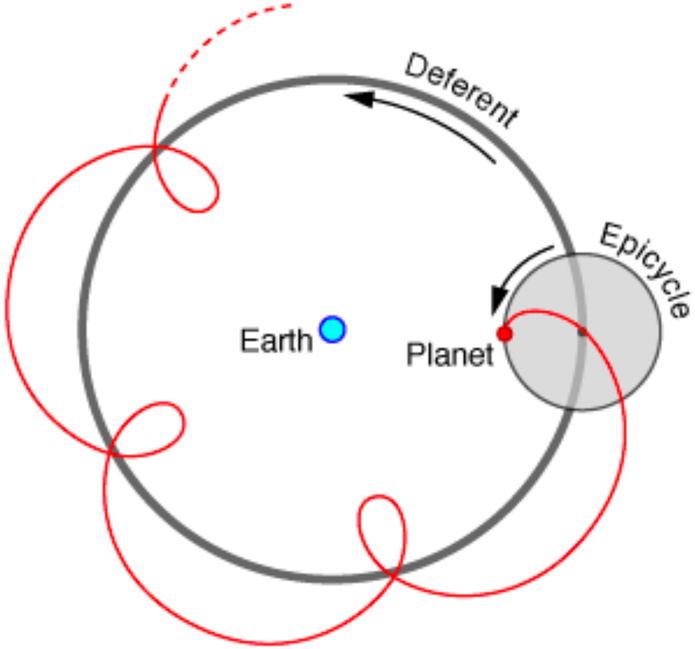
Epicycles - the model of Ptolemy



https://en.wikipedia.org/wiki/Apparent_retrograde_motion

c. 150 CE, credited Hipparchus but probably claimed more credit than deserved

Retrograde motion of Mars in 2005.
Credit astrophotographer Tunc Tezel

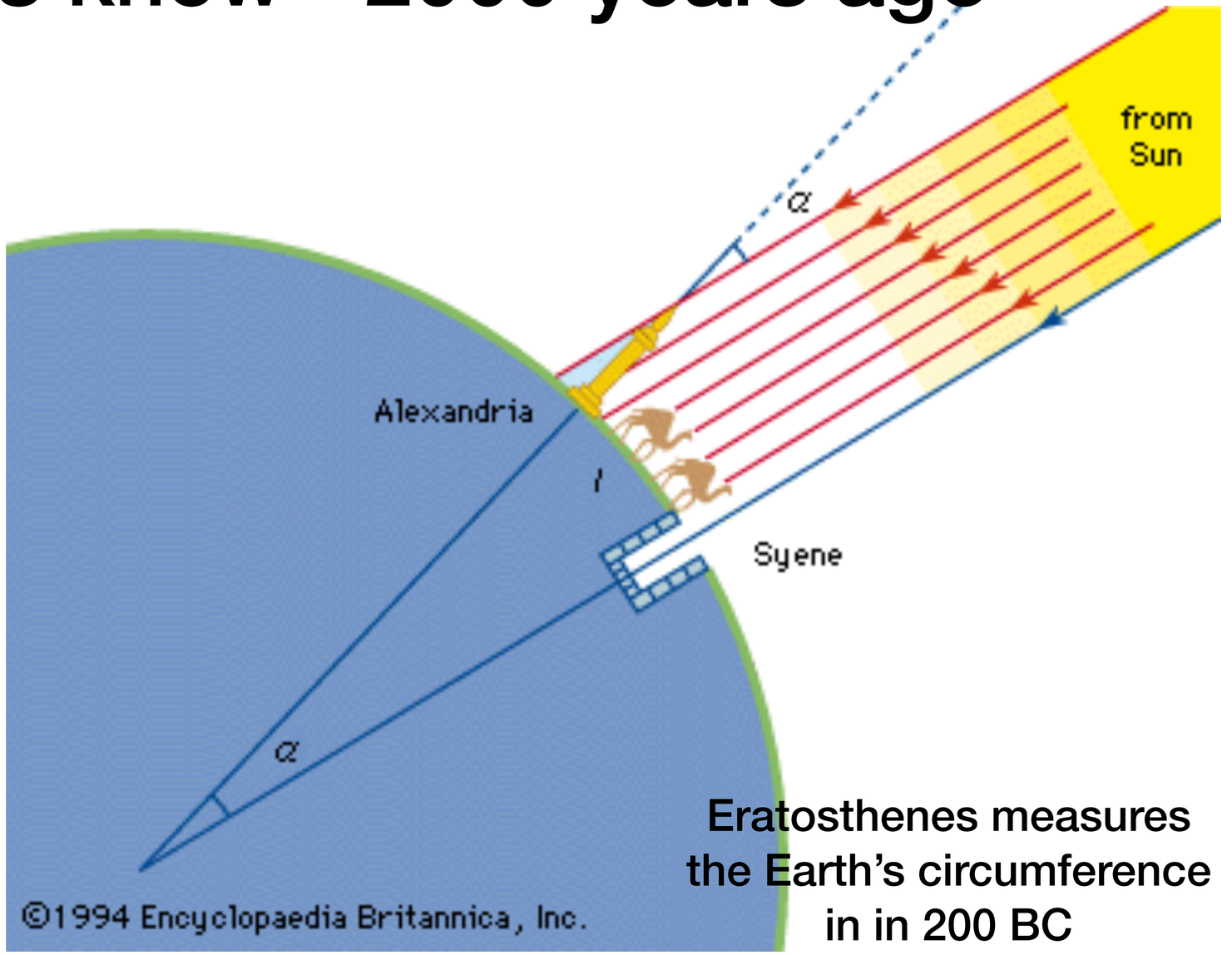


https://physics.weber.edu/schroeder/ua/BeforeCopernicus.html

Epicycle orbited around the Earth, which was offset from the center of the Deferent, at a constant *angular* rate as seen from *another* offset point called the Equant

What the Greeks knew ~2000 years ago

- Accurate radius of the Earth
- Accurate estimate of the Earth-Moon distance and sizes
- Qualitatively correct estimate of the Earth-Sun distance (only wrong by a factor of 20!)
- Precession of the equinoxes not only known about, but accurately estimated
- Length of the year correctly measured to within 7min of true value
- Magnitude system for star brightnesses established (still use today)
- Aristarchus (mid 200s BC) argued for a Sun-centered universe



Eratosthenes measures the Earth's circumference in in 200 BC

Hypatia - first documented female mathematician

Greek mathematician, astronomer, and philosopher in Alexandria, Egypt who taught in the late 300s CE

Primarily preserved past knowledge, a program of her father's that she continued

Was the most famous intellectual of her day, a popular teacher and lecturer of philosophy

Lived at the end of the era of free Greek thought, maintained by Rome until the ascendency of Christianity

Pagans, Christian sects, and Jews openly fought; Hypatia was ultimately murdered by Christian zealots

Fictionalized telling presented in 2009 movie *Agora* (currently available on Amazon Prime)

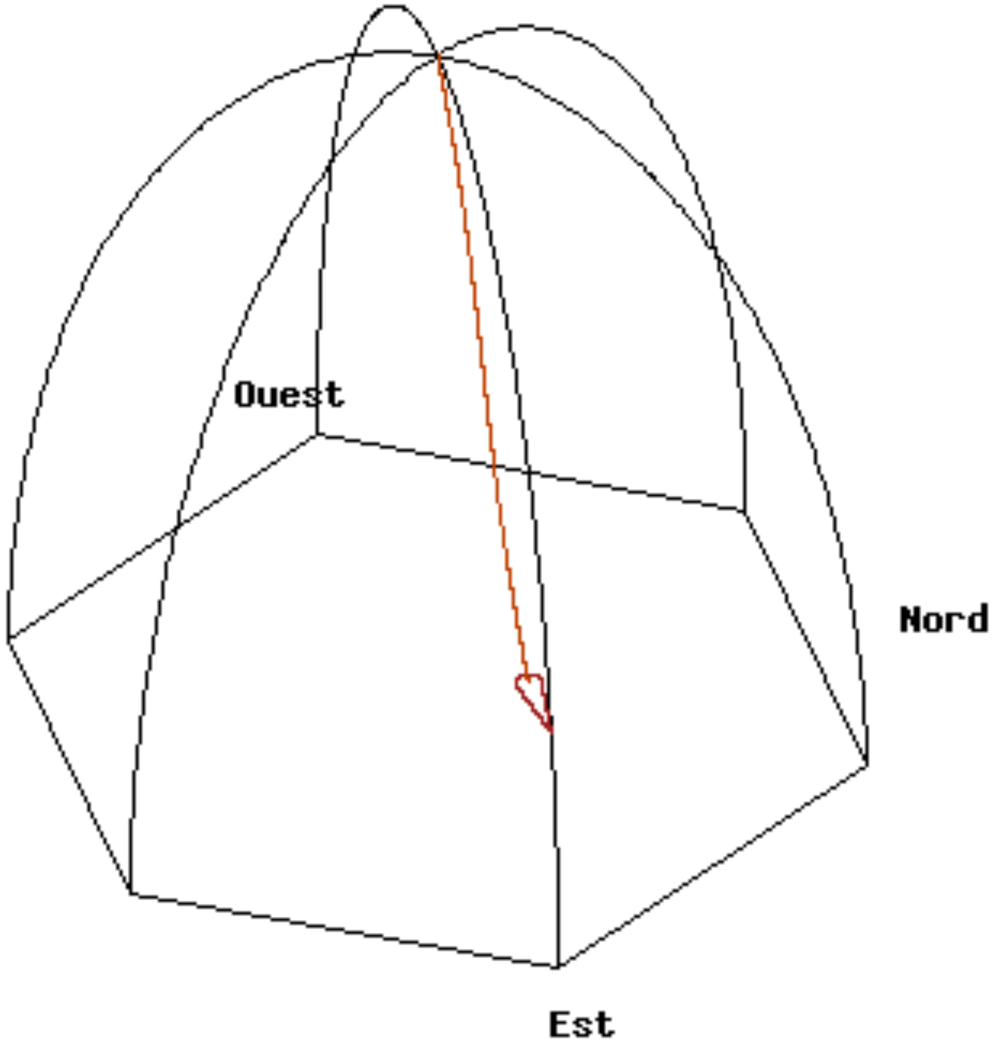
The Earth Moves…

How do we know?

Gravity dominates over other “fictitious” forces

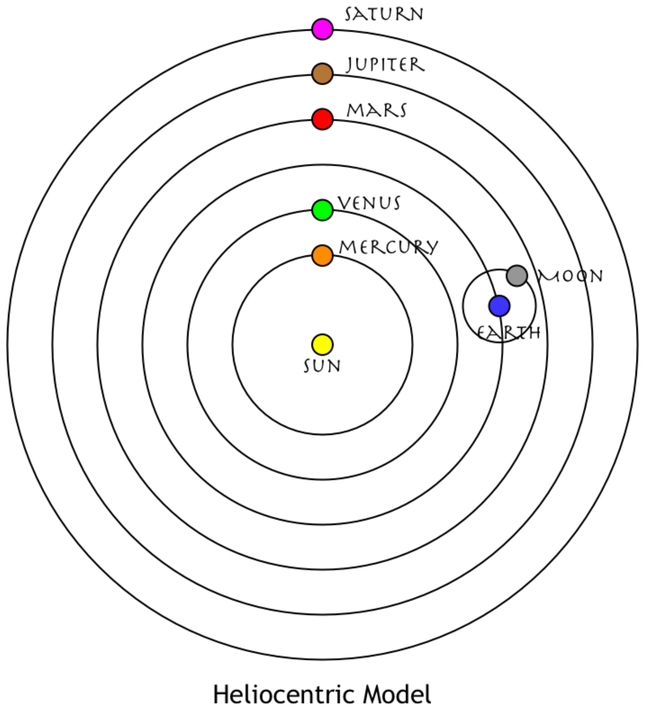
On the equator, Earth’s surface is moving at ~10 m/s relative to the poles.
Creates a “centrifugal force” trying to fling things into space

This velocity depends on your latitude, so ballistic motion north or south is deflected.
(A cannonball shot due N at the equator has a 10 m/s velocity component to the E, but the Earth’s surface rotates slower than this at higher latitudes, so it will be deflected eastward relative to the ground. Also why rockets are launched from Florida towards the Atlantic Ocean.)
This is the “Coriolis force”.

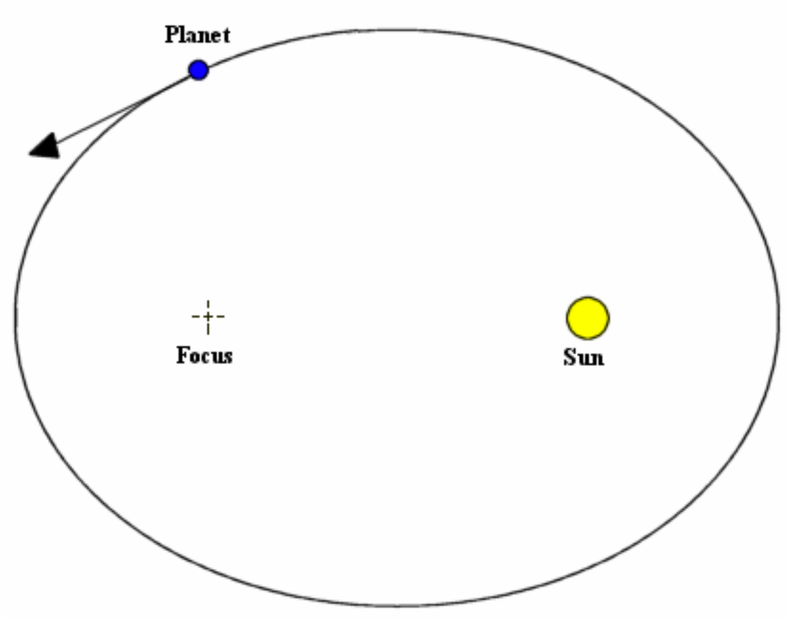


Effects of Earth's Motion

Astronomy becomes a Science



Heliocentric Model



Copernicus → Kepler → Newton

Sun in the right place

Planetary paths mapped out correctly

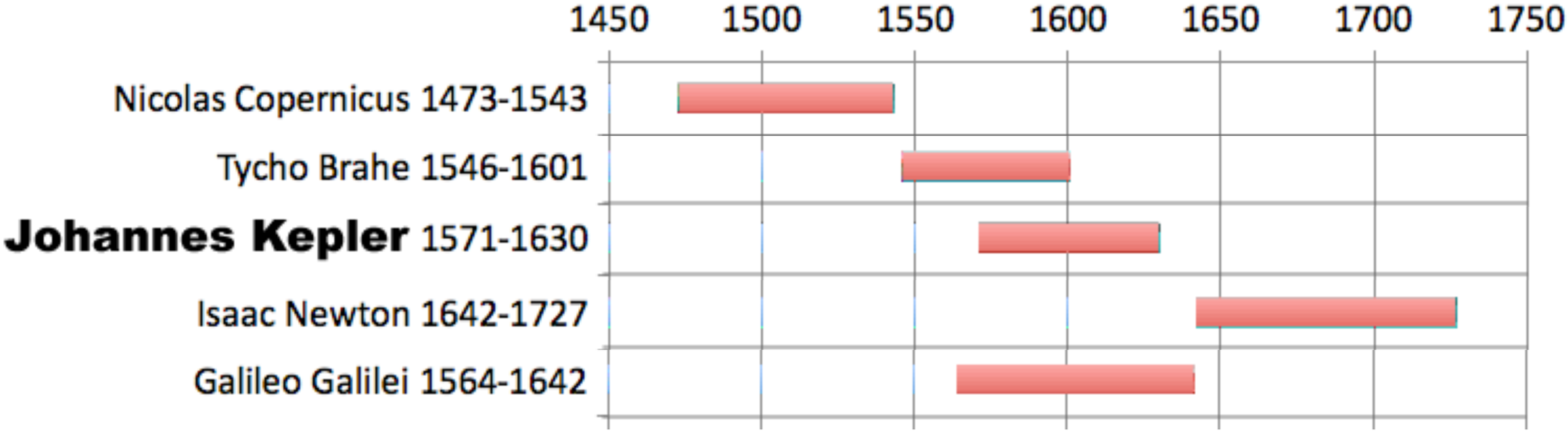
Reason for paths explained theoretically

Astronomy leads to the development of physics

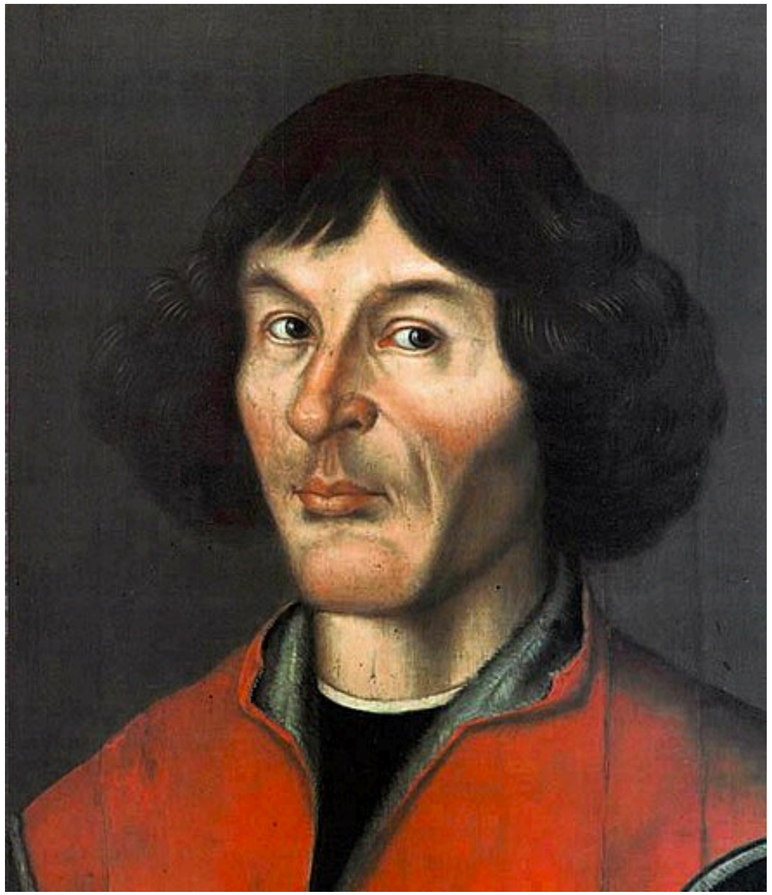
Invention of Science

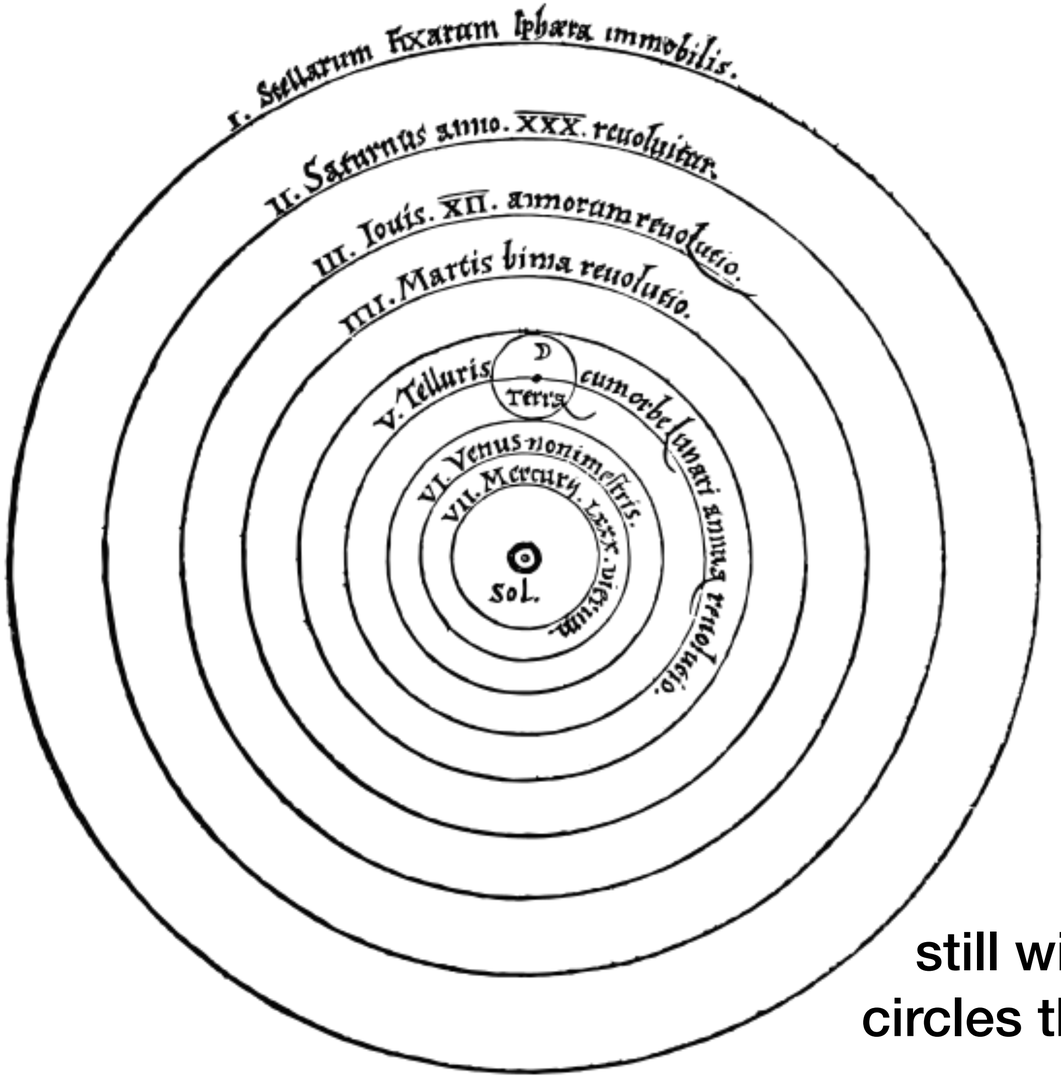
Observations —> Model/Theory —> Predictions

Occam's Razor



Copernicus politely defies church orthodoxy





still with the circles though…

Tycho Brahe's dope observations

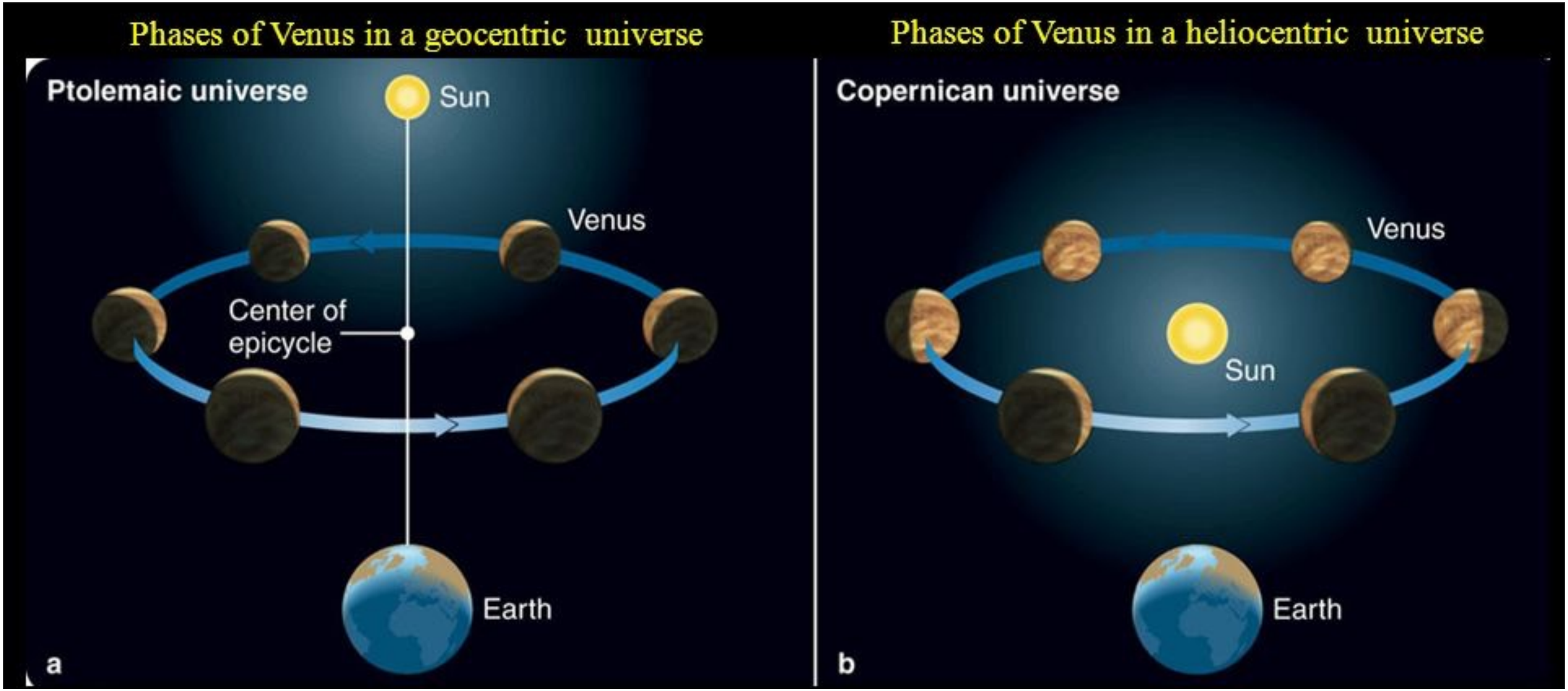
Made the best astronomical measurements before the age of the telescope

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

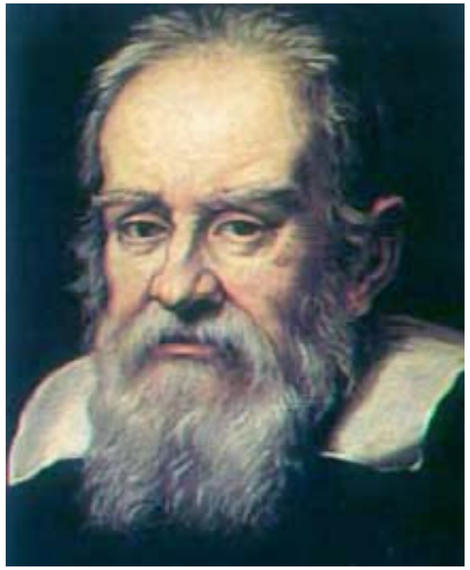
Built a hybrid model to reconcile the simpler Copernican idea with a stationary Earth

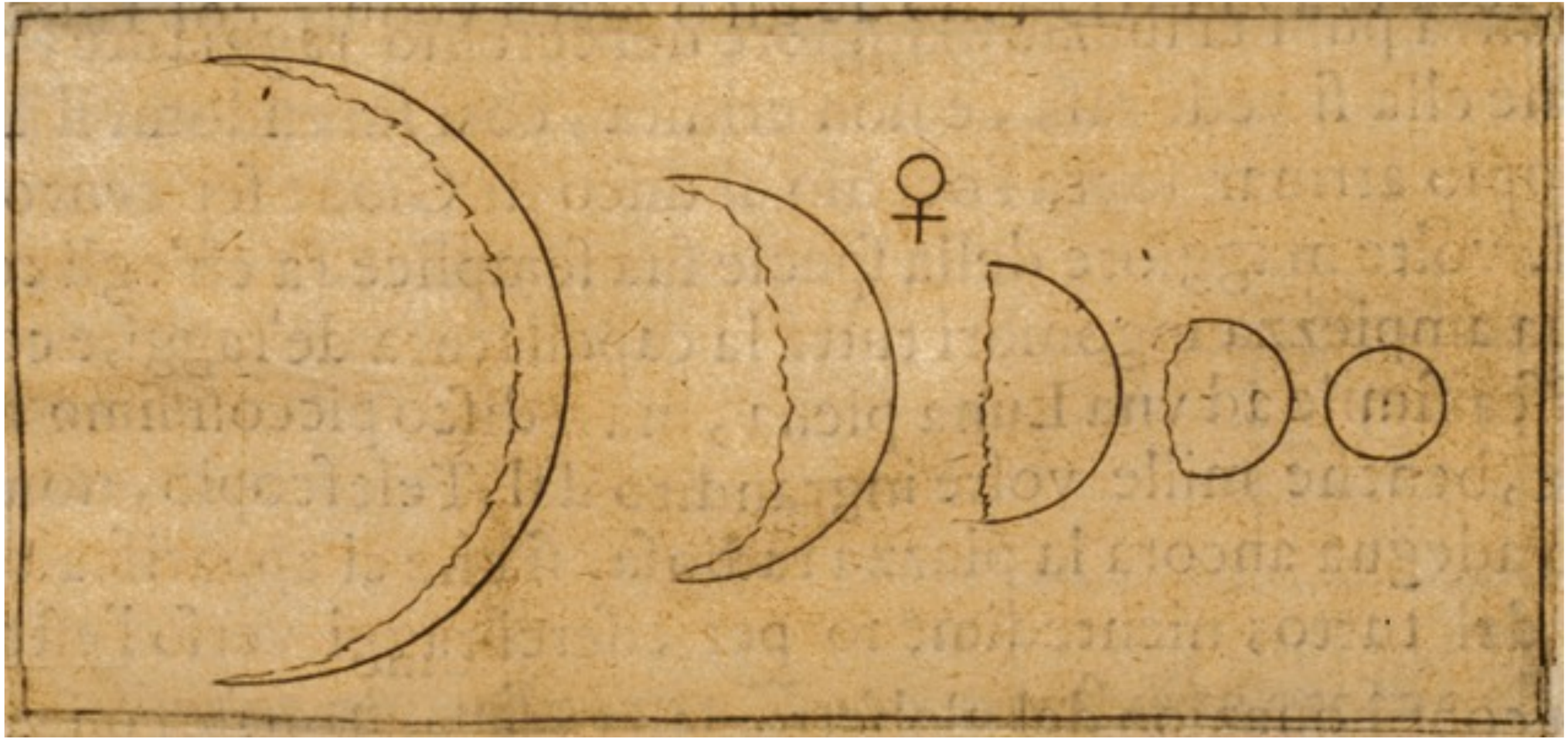
Had a metal nose, died heroically

Galileo performs a “crucial experiment”

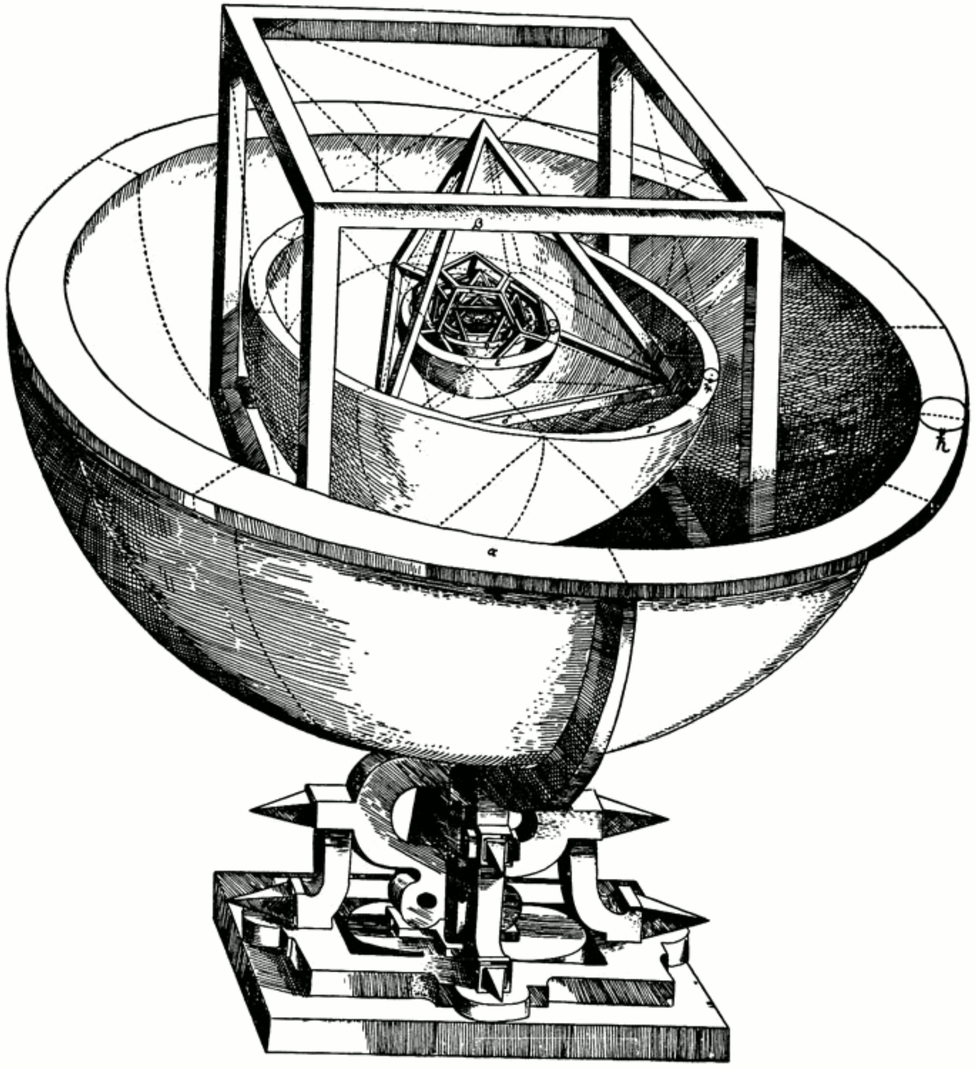


Galileo’s observations of the





Kepler's Insight



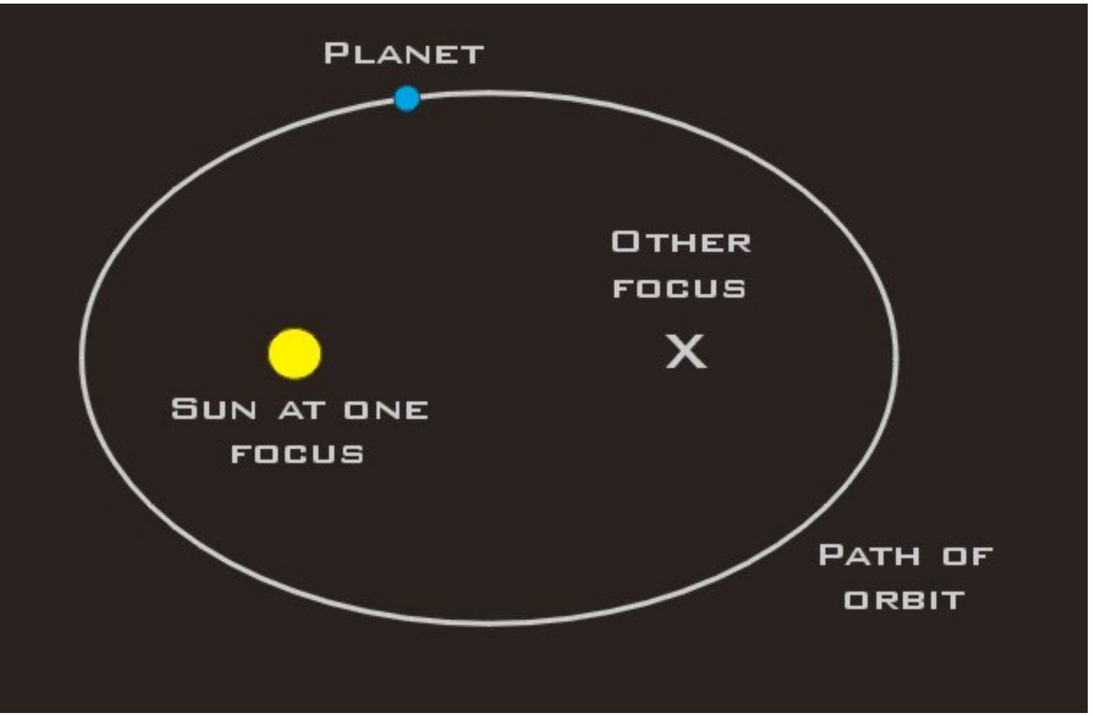
- trusted Tycho's data
- thought Copernicus' Sun-centered model was right
- believed Ptolemy's and Copernicus' assumption that orbits were circular was correct

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

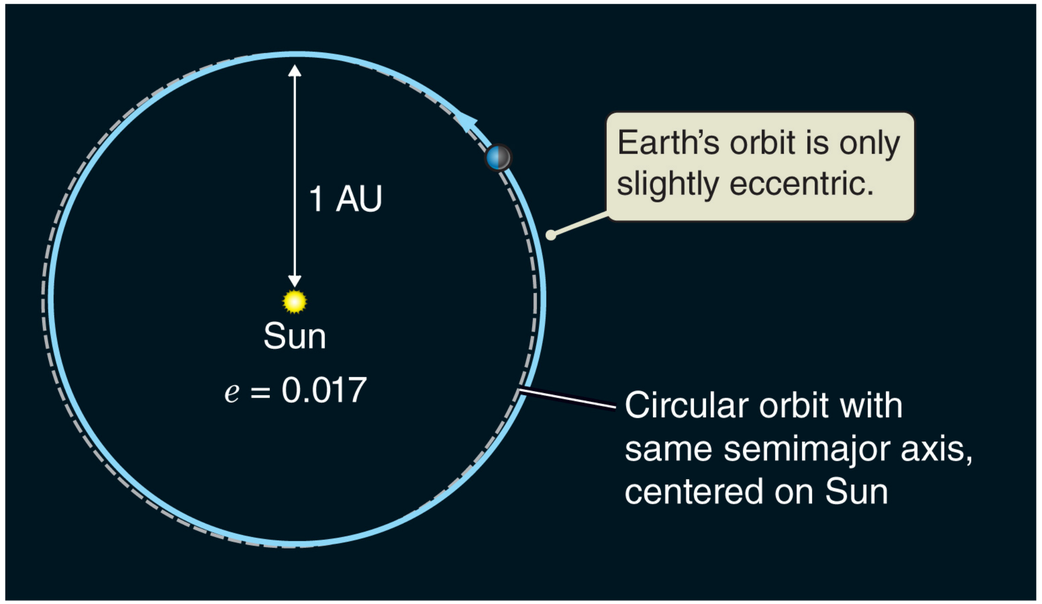
Like a good scientist, Kepler trusted the data most and abandoned circles

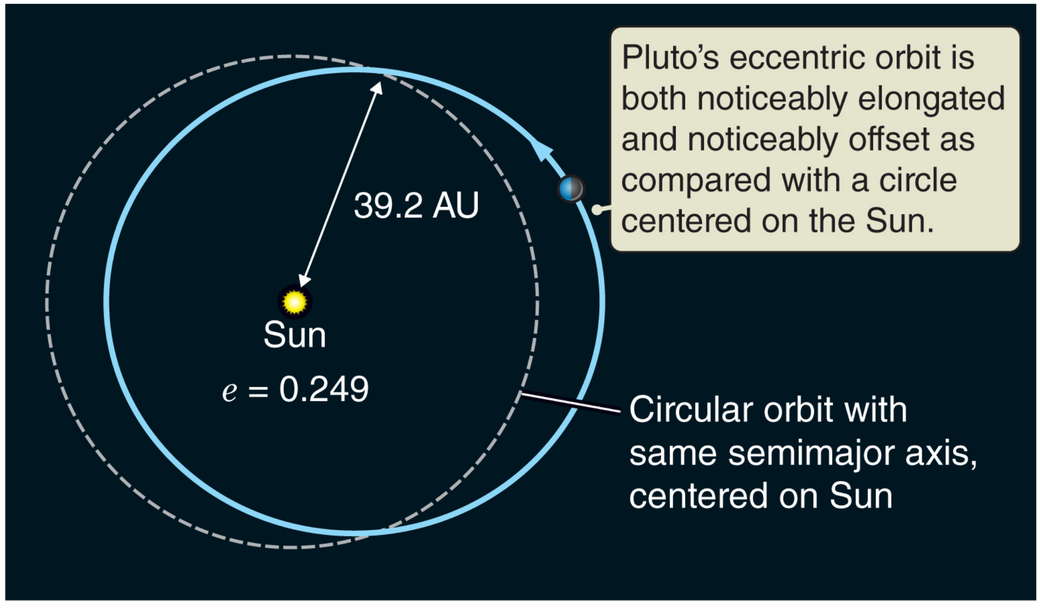
Kepler's 3 Laws!

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



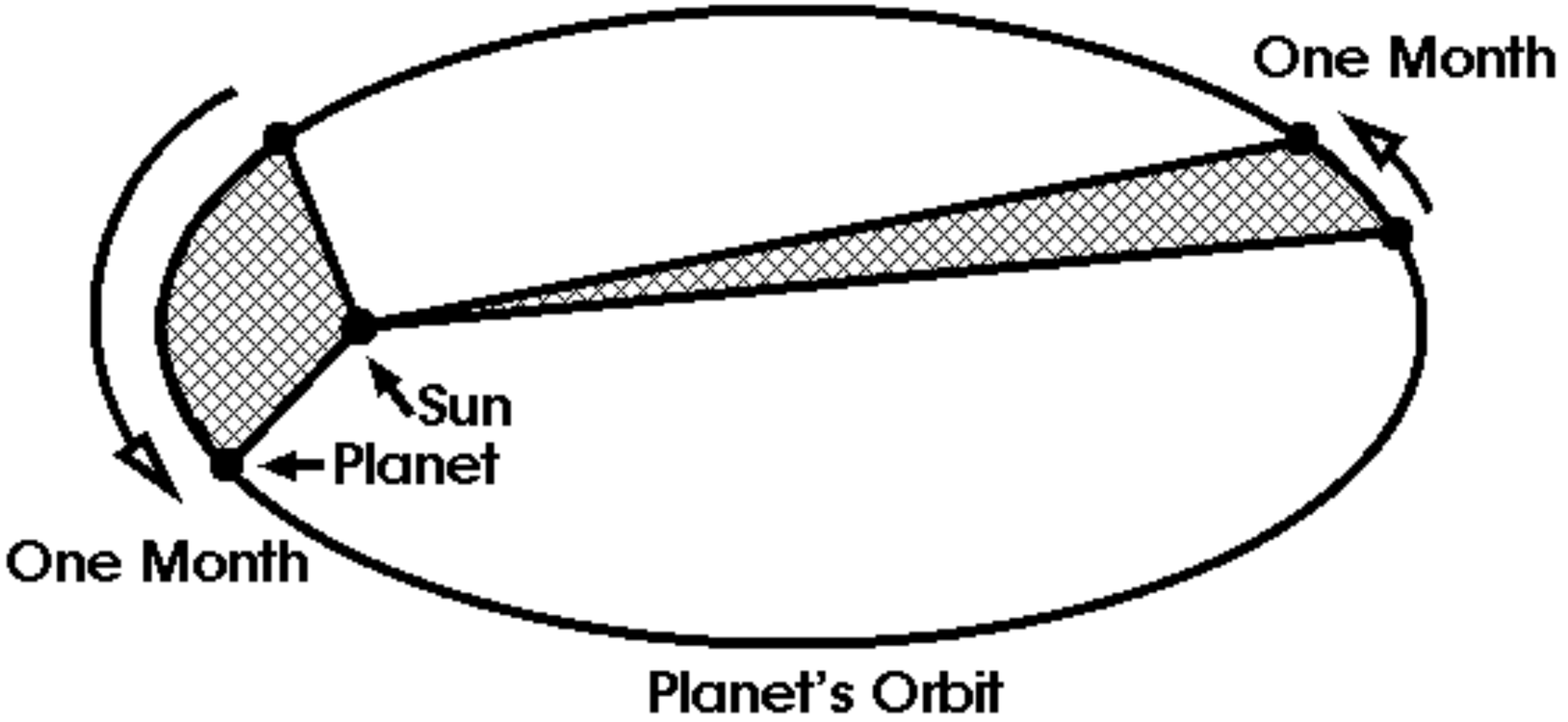
Major Axis





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"



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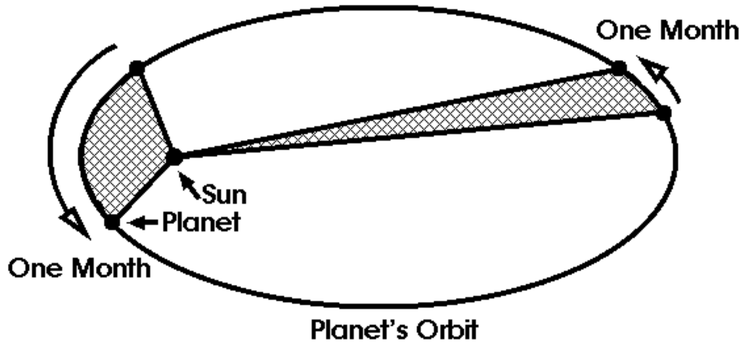

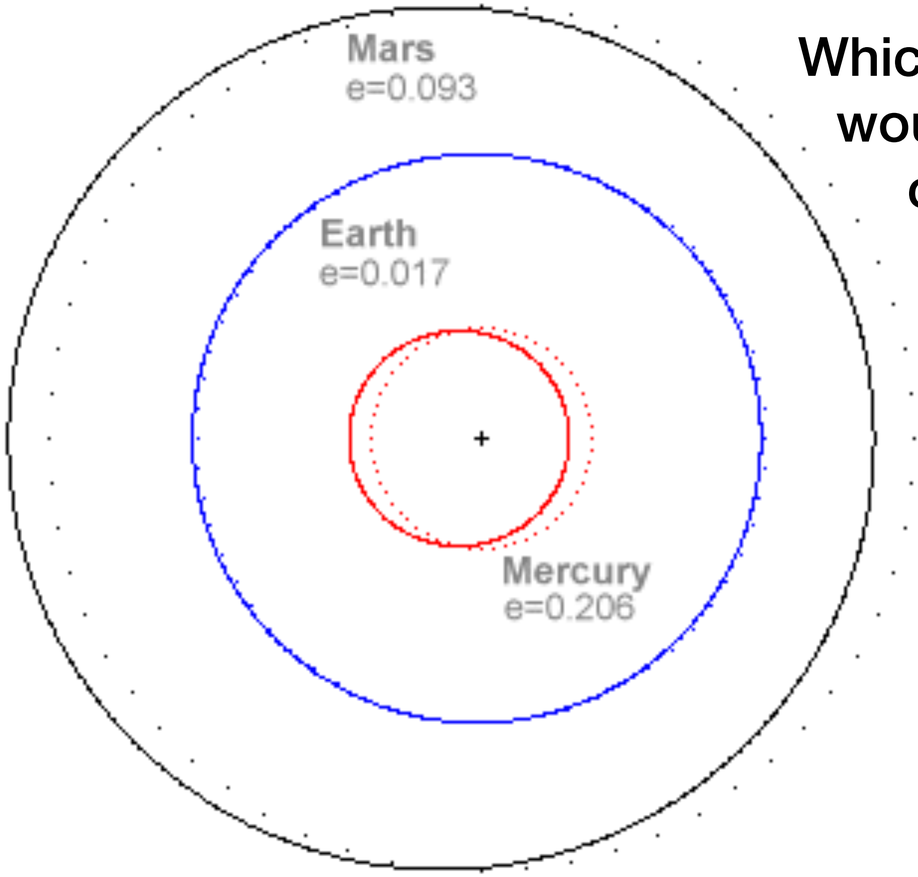

Which of the three planets shown would experience the smallest change in orbital speed?

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).