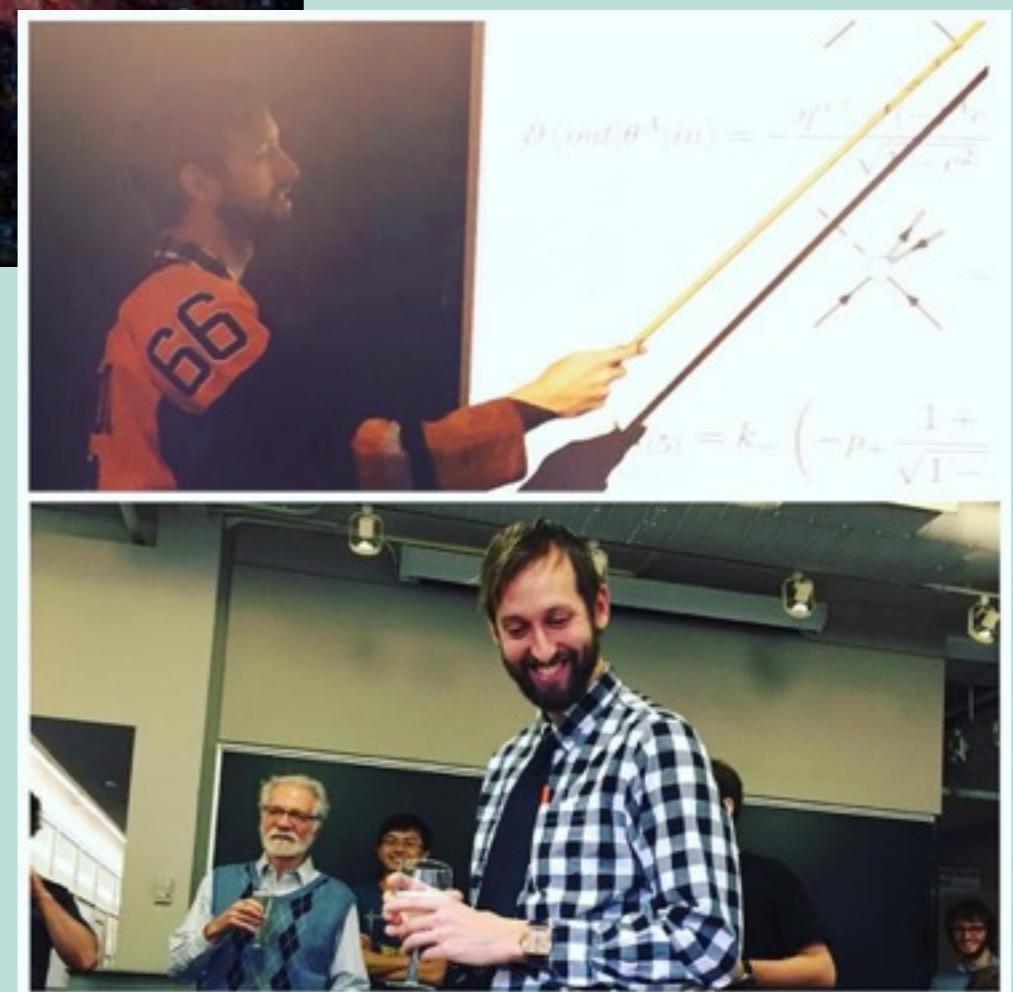




Astronomy

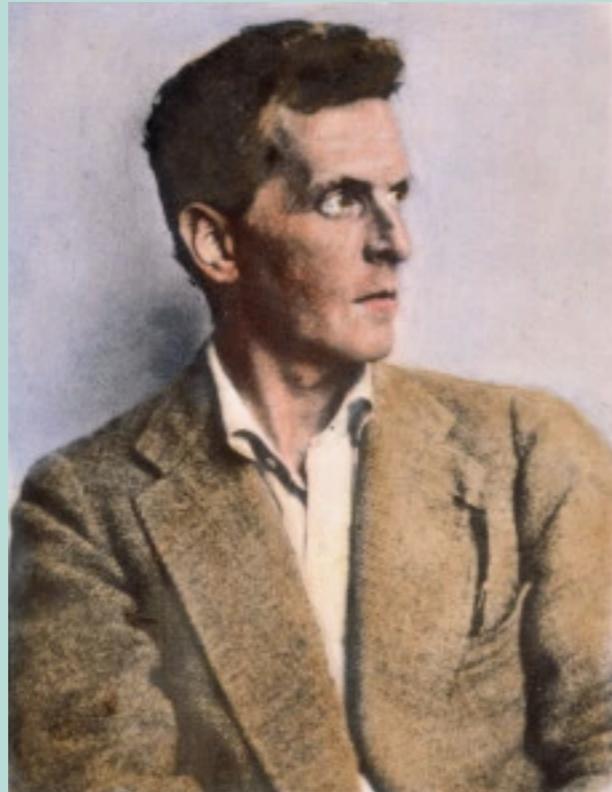
**Lecture 1:
Foundations of
Astronomy and the
Scientific Method**

with your host:



Coop

What is *Science*

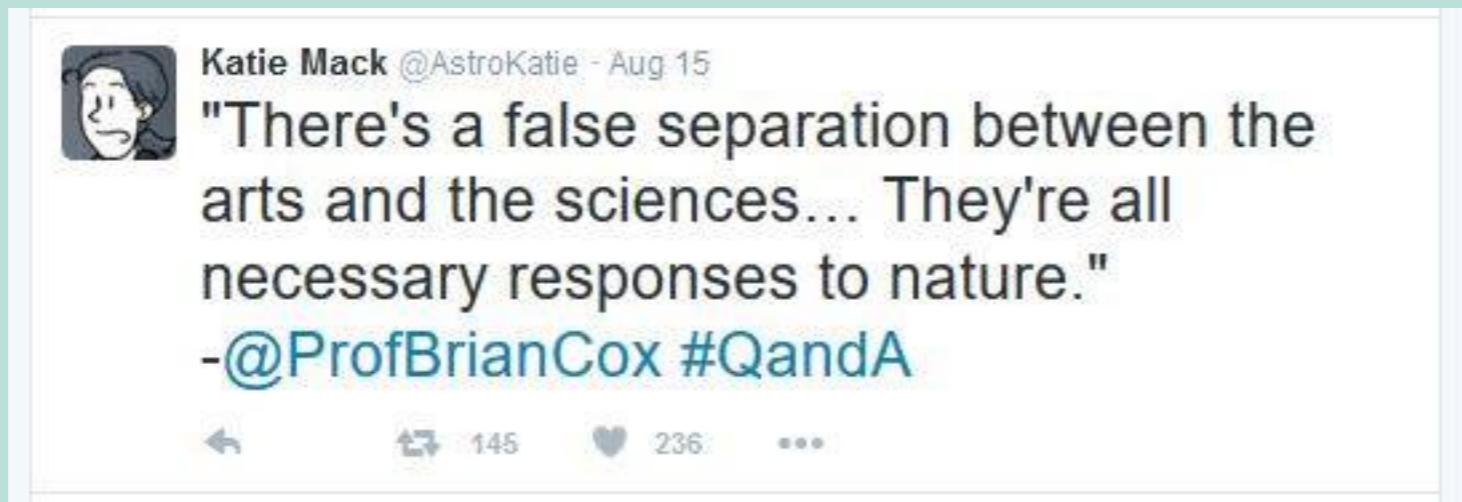


“The meaning of a word is the use in its language”

-Philosophical Investigations (1953)

What is *Science*

- Science is *not* a list of facts.
- Science is a set of *practices* which we collectively agree upon to determine what *counts* as a fact.
- The practice of science is *useful*.
- The practice of science is *on going*.
- Science is a global pursuit



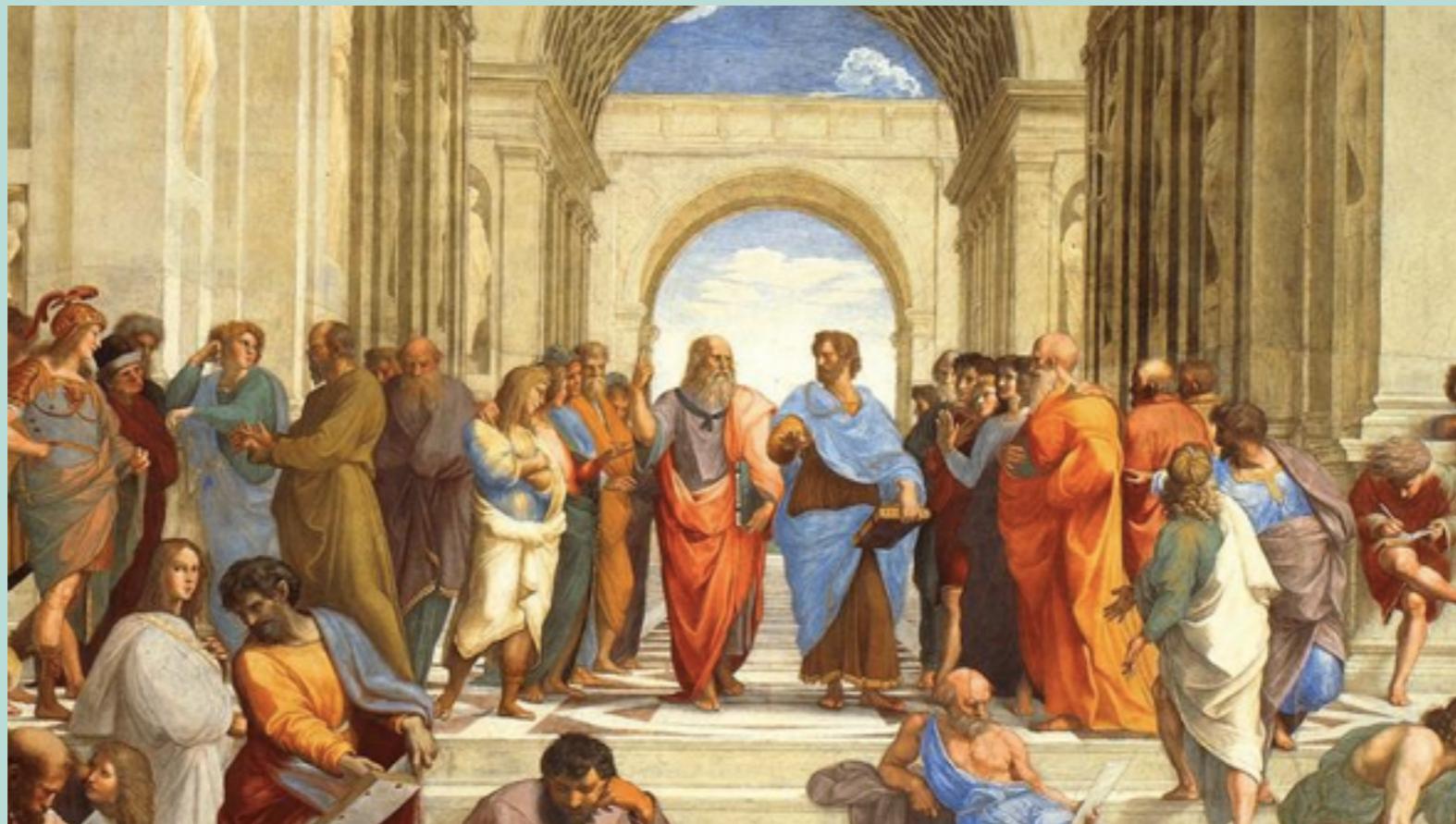
Katie Mack @AstroKatie - Aug 15
"There's a false separation between the arts and the sciences... They're all necessary responses to nature."
-@ProfBrianCox #QandA

145 236 ...

What is the *Practice* of Science

- The scientific method

What is *not* the scientific method?

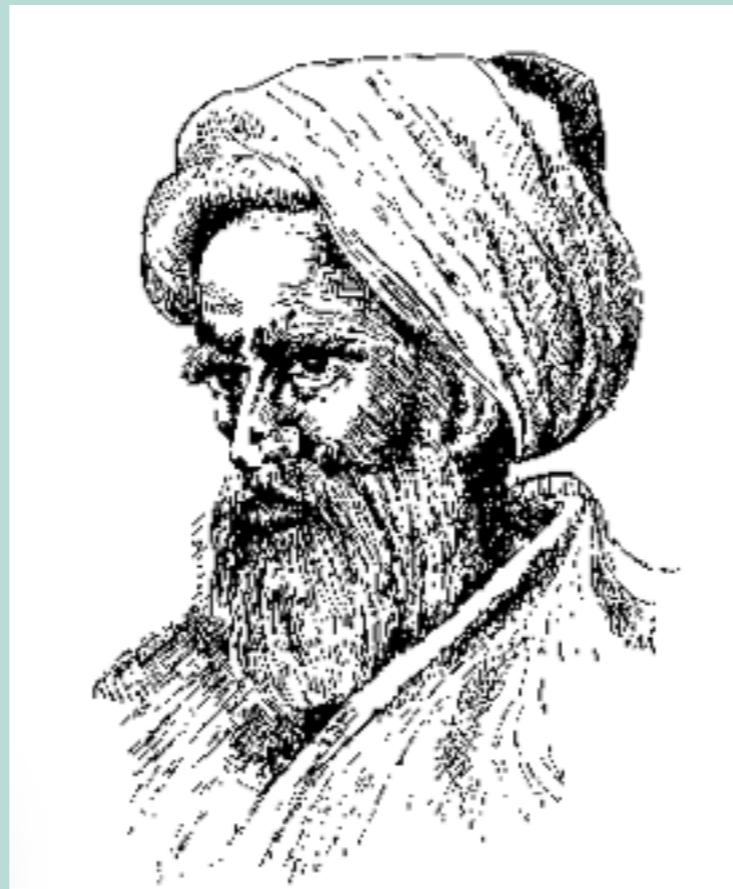


natural philosophy

What is the *Practice* of Science

- The scientific method

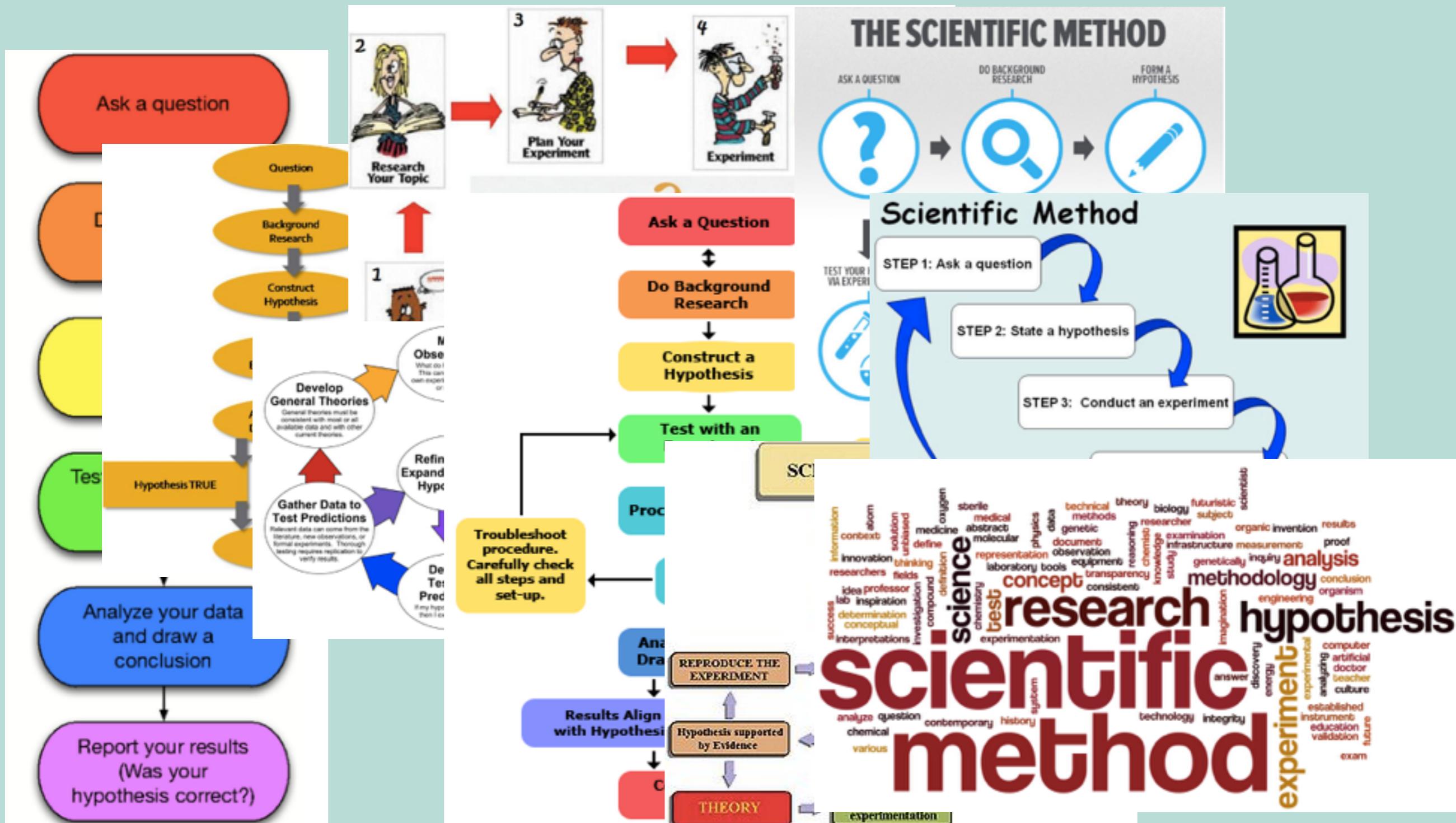
What *is* the scientific method?



Alhazen: 965–1039

What is the *Practice* of Science

- The scientific method is FLOW CHARTS



What is the *Practice* of Science

- Make a hypothesis about an observed phenomenon or one to be observed.
 - Basically... a narrative.
- Identify the domain of applicability of the hypothesis and test it.
- Repeat. Modify hypothesis as needed.

What is the *Practice* of Science

The kicker.... What *counts* as a good narrative.

This is what they don't tell you in school. The answer?
Depends on who you ask.

- It should be *simple...*
 ...as possible
- It should be *robust*
- It should be *broad in scope*
- It should be *falsifiable*.

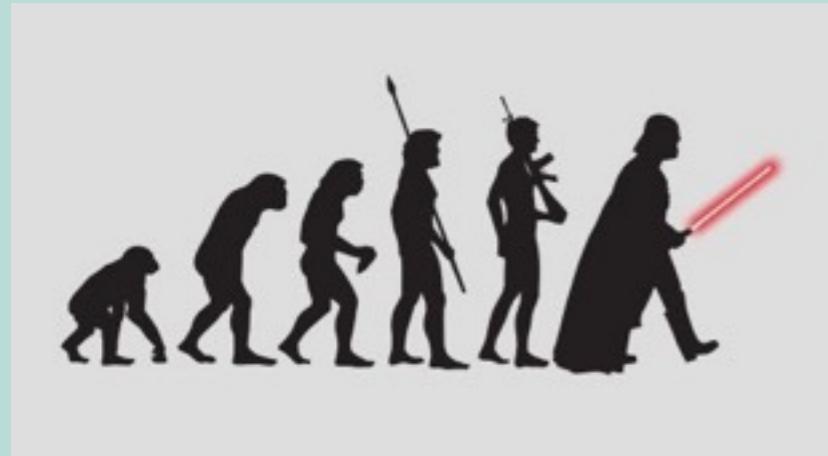
What is Science About?

Science requires practice for arriving at consensus. Thus science is by definition about the phenomena we have in common with others practicing science. We call these particular types of phenomena “Nature” as opposed to “emotions” and “dreams” and “feelings”.

This course will be about a set of phenomena that involves enormous systems like our planet as a whole, our solar system, our galaxy, and our universe.

Astronomy. Go Big. Or Go Home.

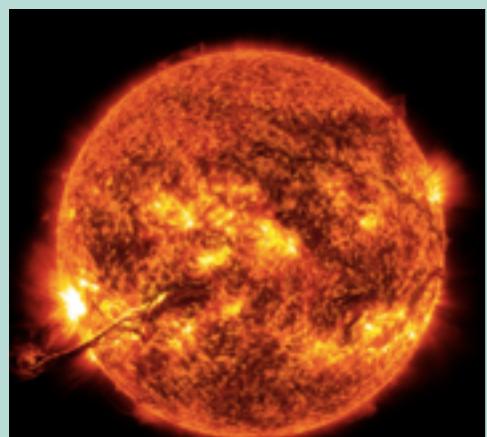
Scales



← →
 10^0 m

← →
 10^3 m

← →
 10^6 m



← →

10^9 m



← →

10^{12} m



← →

10^{20} m



← →

10^{23} m

Scales

These numbers are BIG. Humans are much better at comparing big *times* than big *distances*

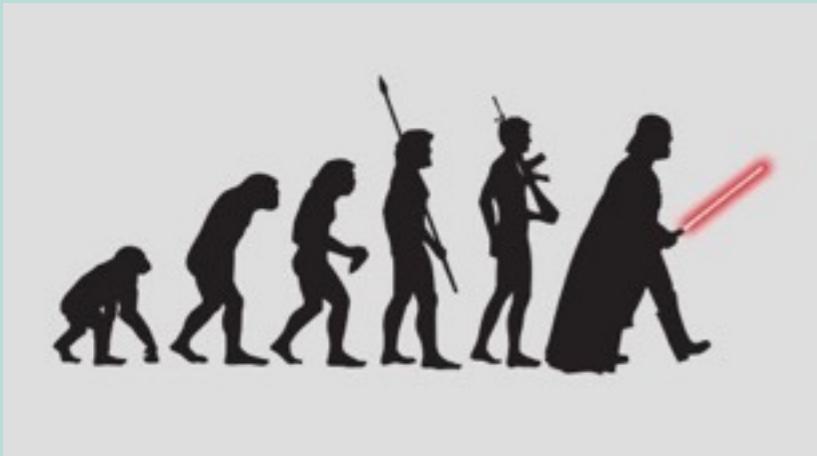
(you've been alive $\sim 10^8$ seconds)

In order to convert big distances to small times, we need to think about something that goes really *fast*

The speed of light in vacuum is $\sim 3 \times 10^8$ meters/second

“c = 1”

Scales



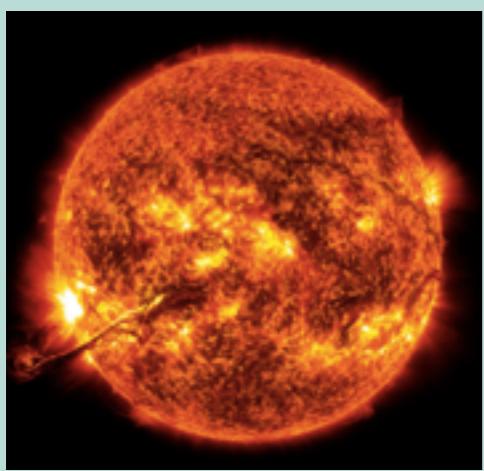
3 ns
(CPU clock cycle)



1 μ s (high speed
strobe light)



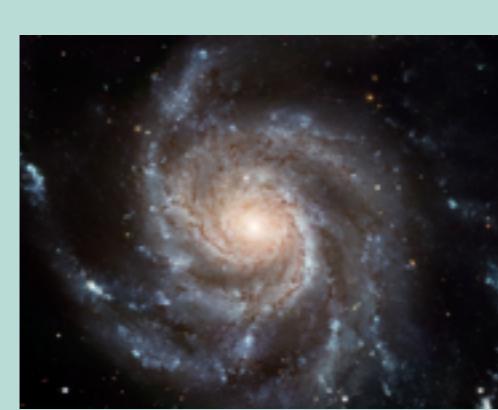
.05 s
(blink)



3 s



55 min



10,000 years

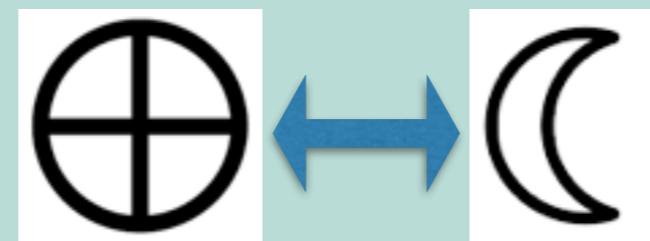


10 million
years

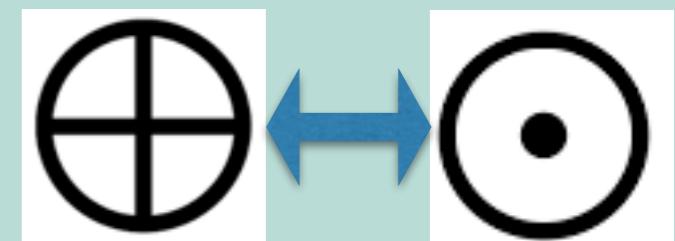
Scales: Some useful stuff



1 ns



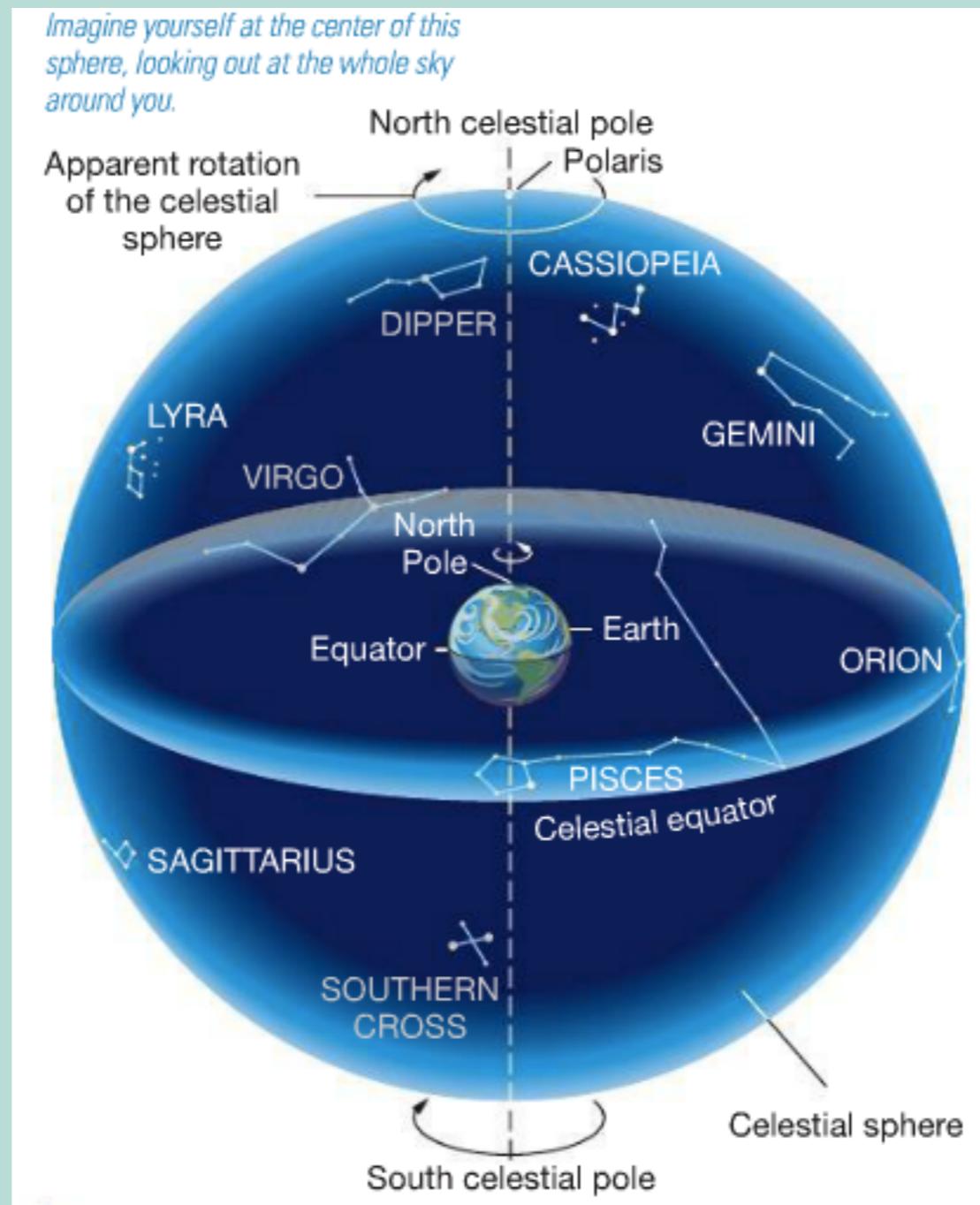
2 s



8 min

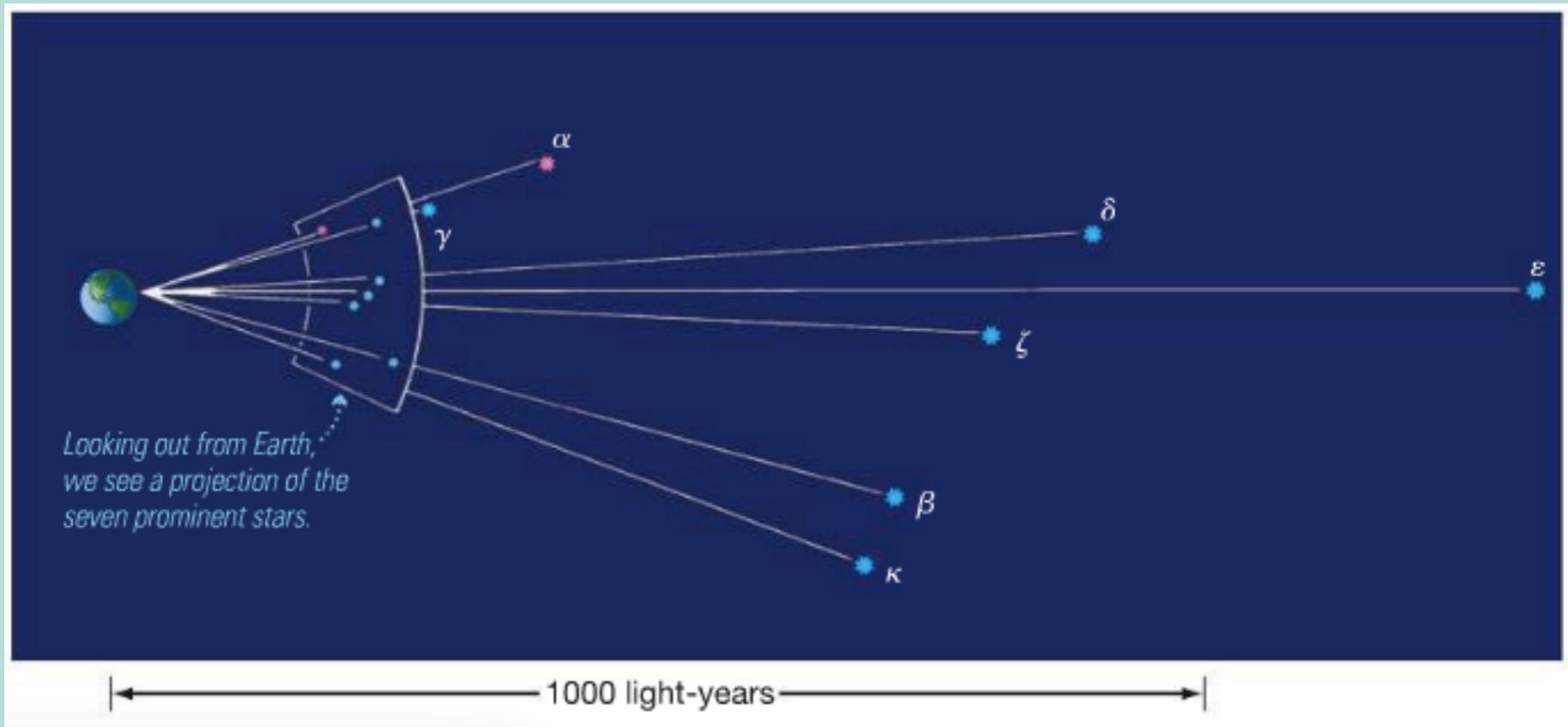
- $10^3 \text{ s} = 16 \text{ minutes}$
- $10^6 \text{ s} = 10 \text{ days}$
- $10^9 \text{ s} = 30 \text{ years}$
- 1 year $\sim \pi \times 10^7 \text{ seconds}$

“The Celestial Sphere”



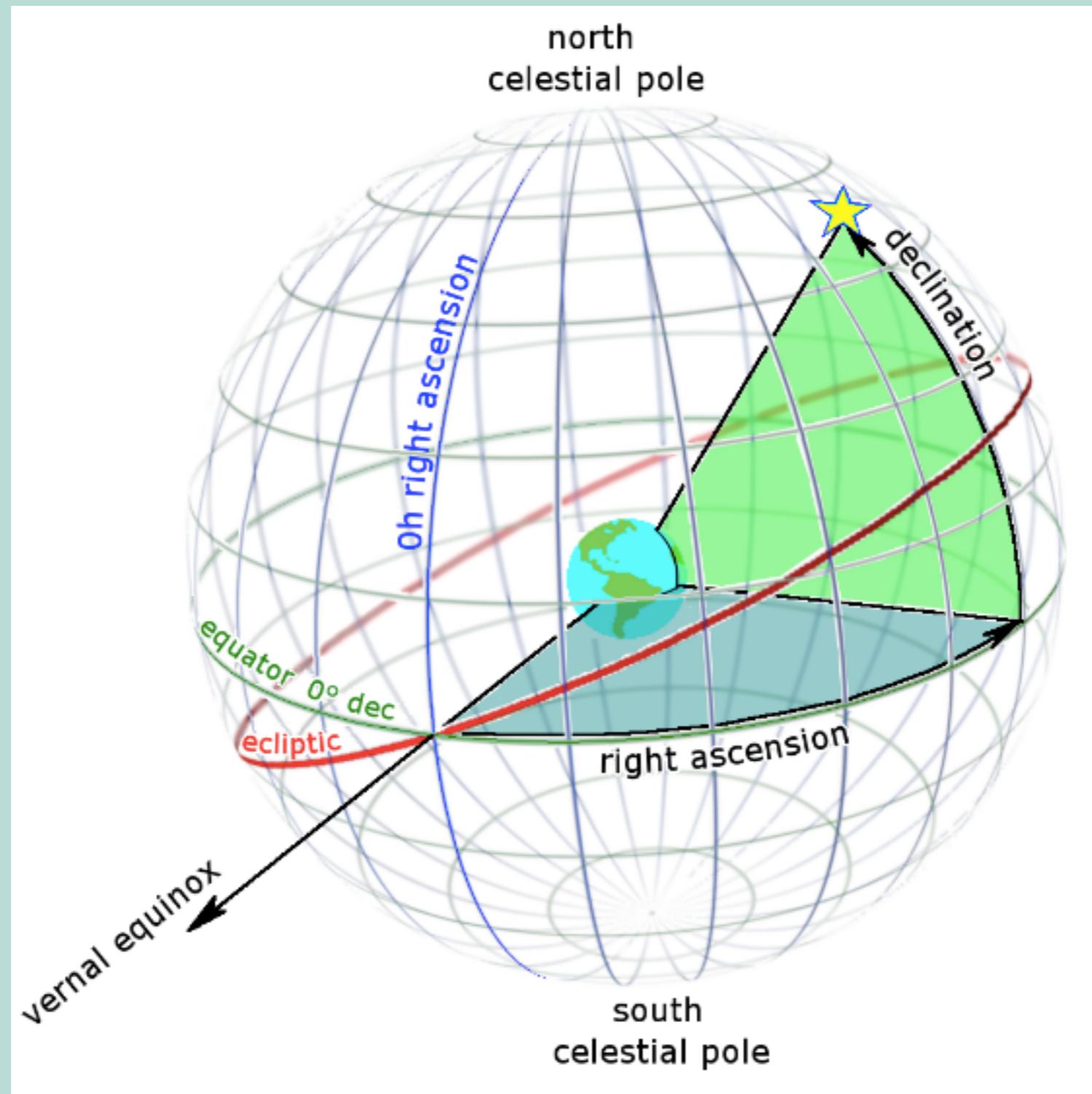
~9000 (4500/hemisphere) stars “visible to the naked eye”

“The Celestial Sphere”

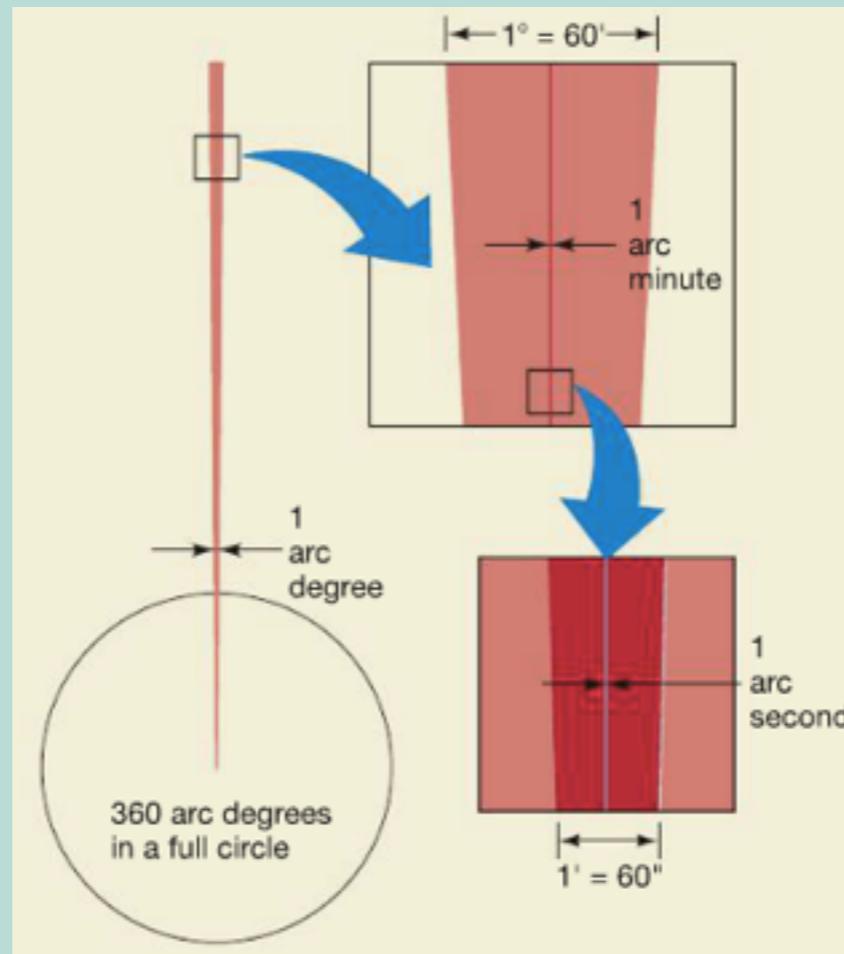


There's about 10^{12} stars in the galaxy
There's about 10^{11} galaxies in the universe
-> 1 ‘mole’ of stars in the universe.
(grains of sand on earth, atoms in your fingernail etc)

“The Celestial Sphere”



Measuring the Sphere.



$$1 \text{ degree} = .0175 \text{ rad}$$

$$1 \text{ arcminute} = 3e-4 \text{ rad} = .0167 \text{ deg}$$

~2 miles

$$1 \text{ arcsecond} = 5e-6 \text{ rad} = .0003 \text{ deg}$$

~here to PennState

$$1 \mu\text{arcsecond} = 5e-12 \text{ rad} = 2.7e-10$$

>here to sun

The Earth Moves Around the Sun.

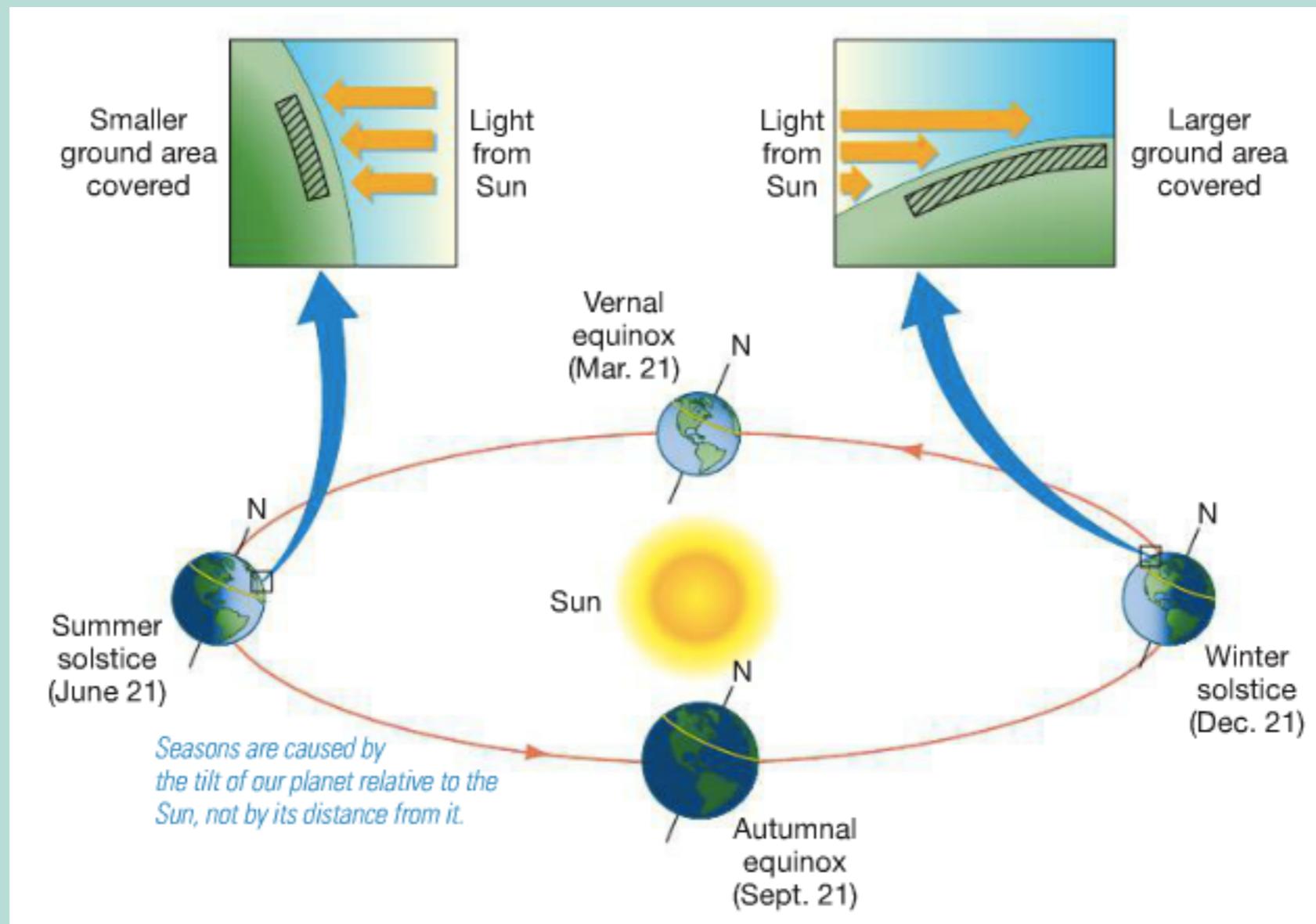


23 hours 56 min
 $360 \text{ deg}/365 \text{ days} \times 15 \text{ deg/hour} = 3.9 \text{ minutes}$



24 hours (by definition)

The Earth Is Tilted.



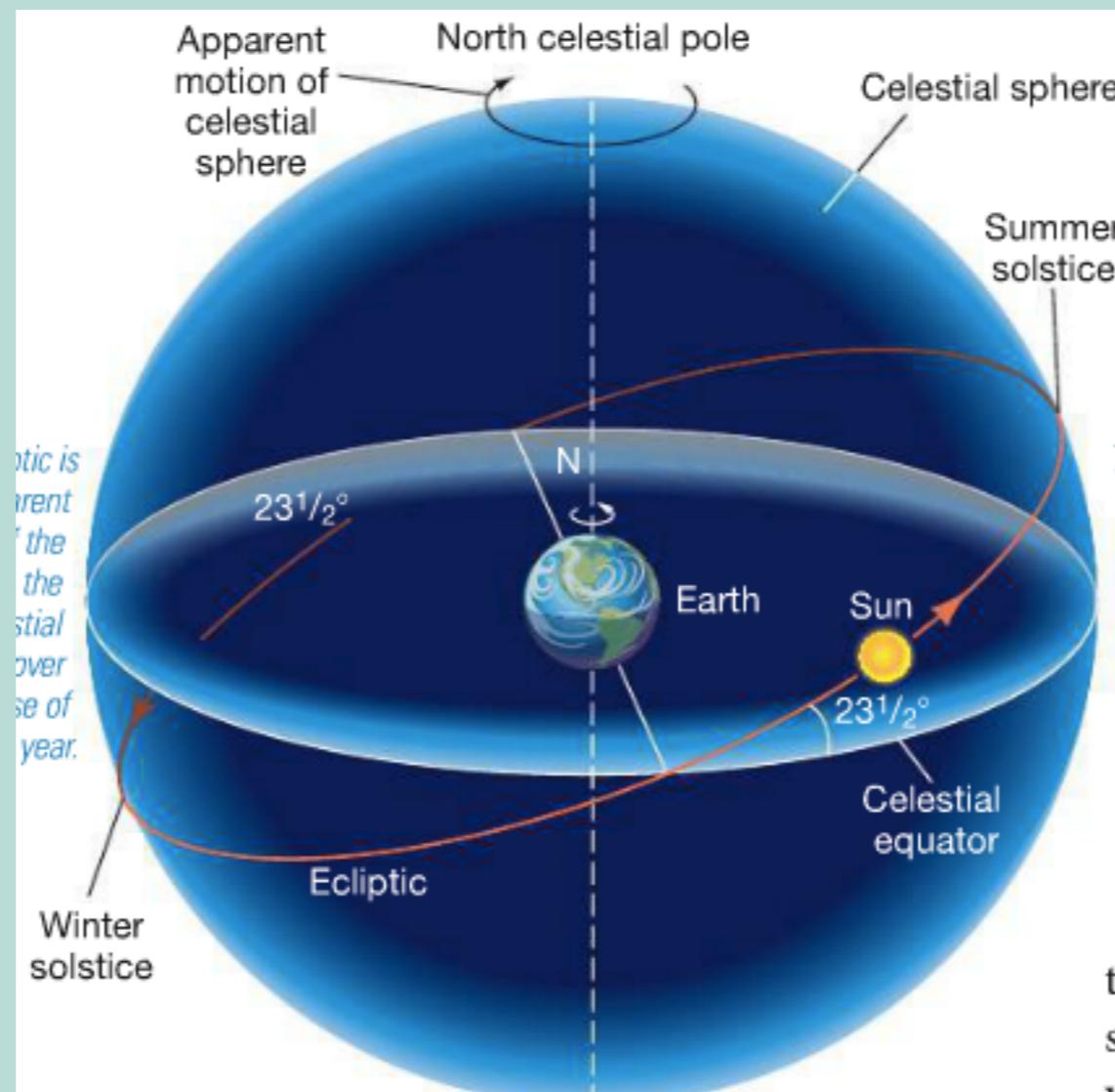
23.5 degrees

The Earth Is Tilted.



The north star, “Polaris” lies on the axis of rotation

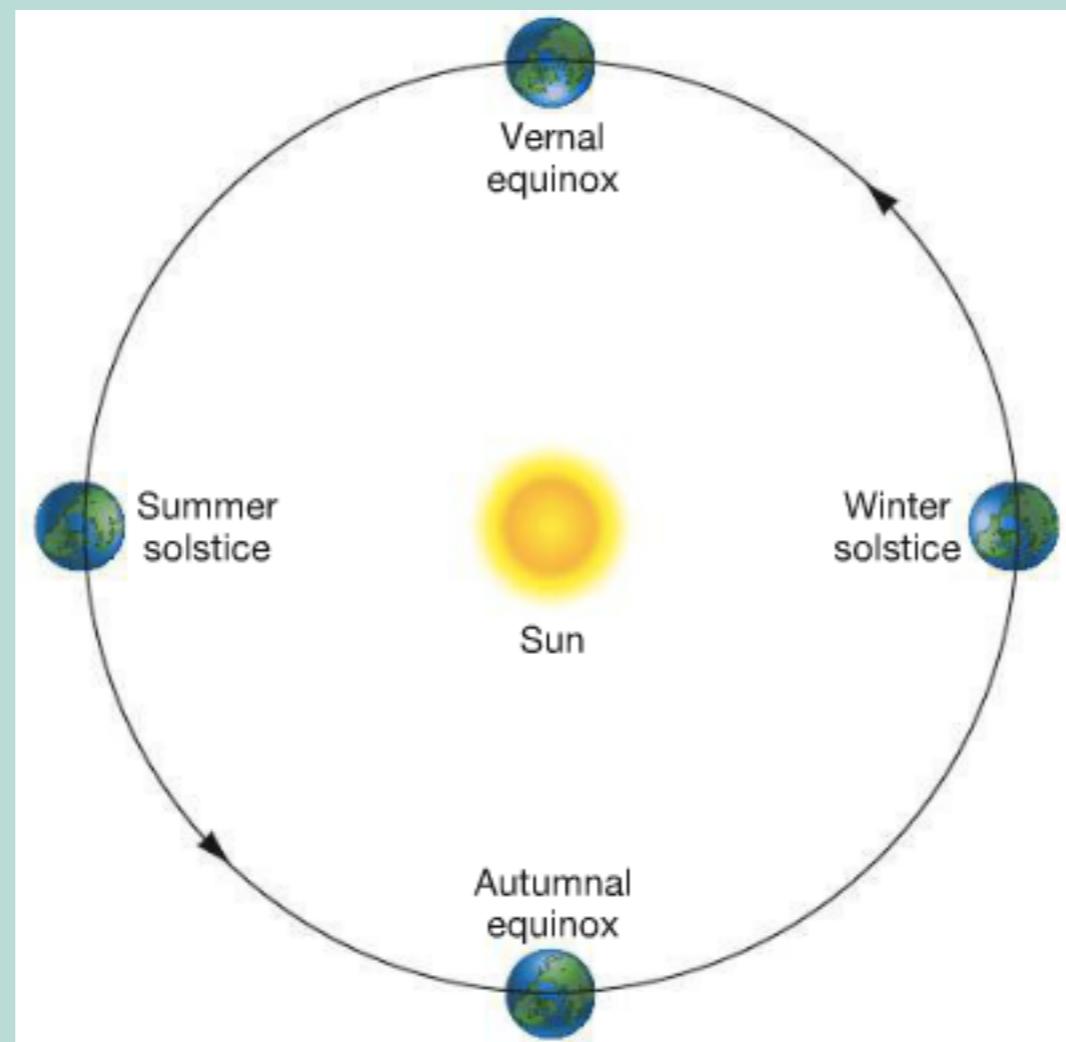
The Earth Is Tilted.



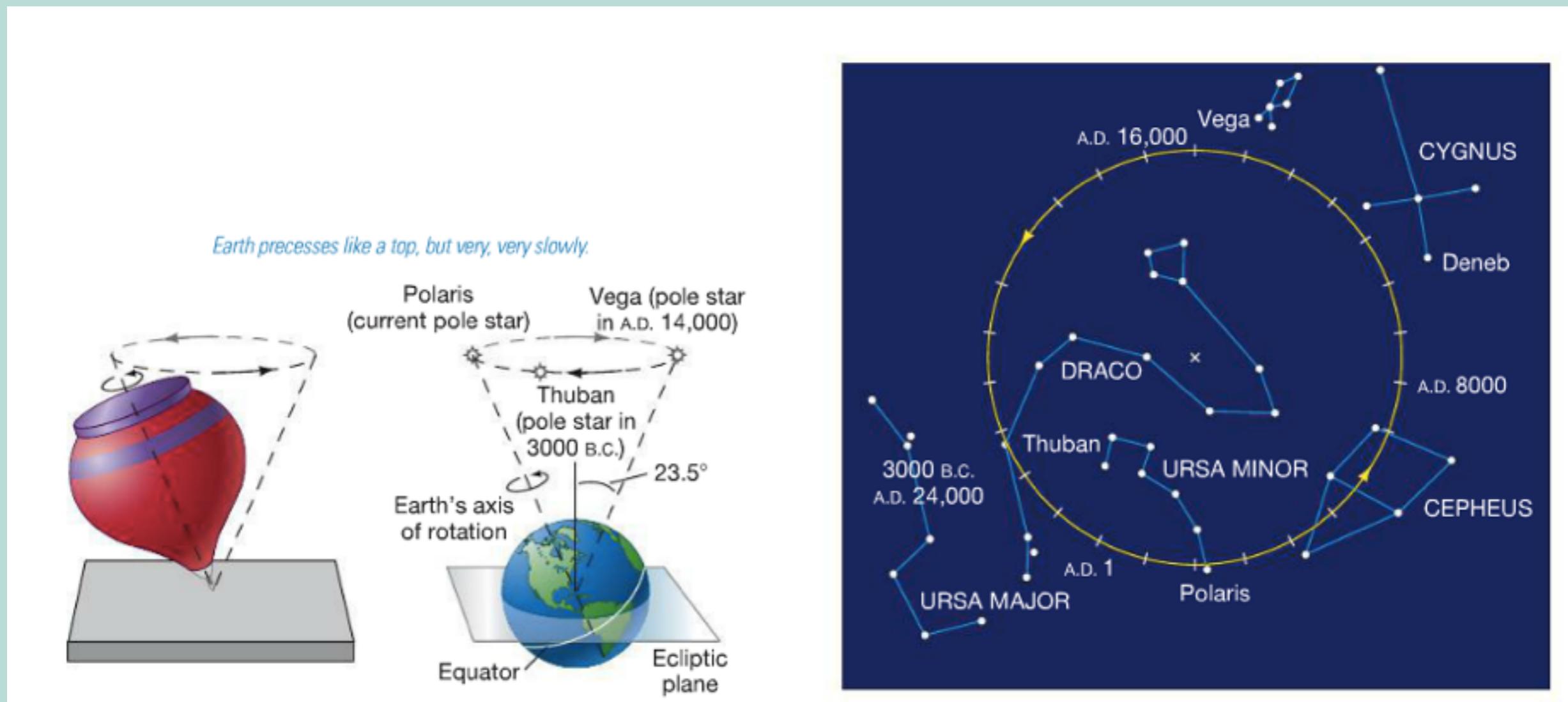
The Zodiac



Equinoxes



The Earth Precesses.

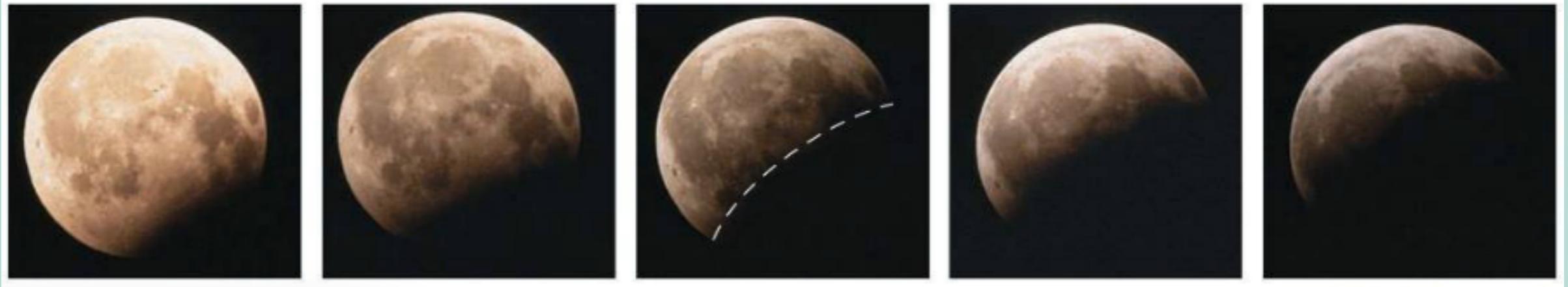


Full rotation every ~26,000 Years

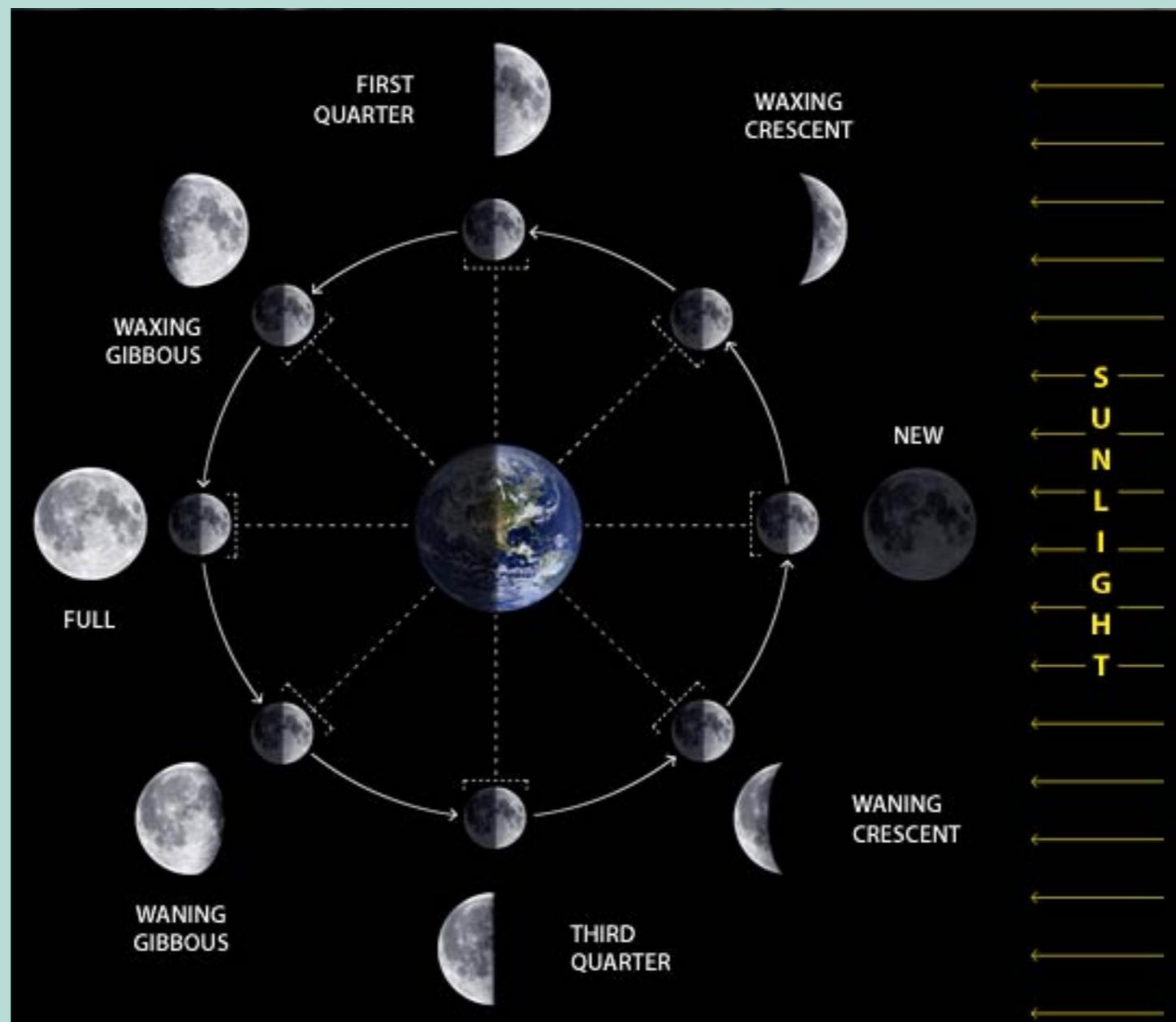
tropical year = vernal equinox to vernal equinox =
365.2422 mean solar days. (gregorian)

sidereal year = one complete rotation w/r/t fixed
stars = 365.256 mean solar days. (julian)

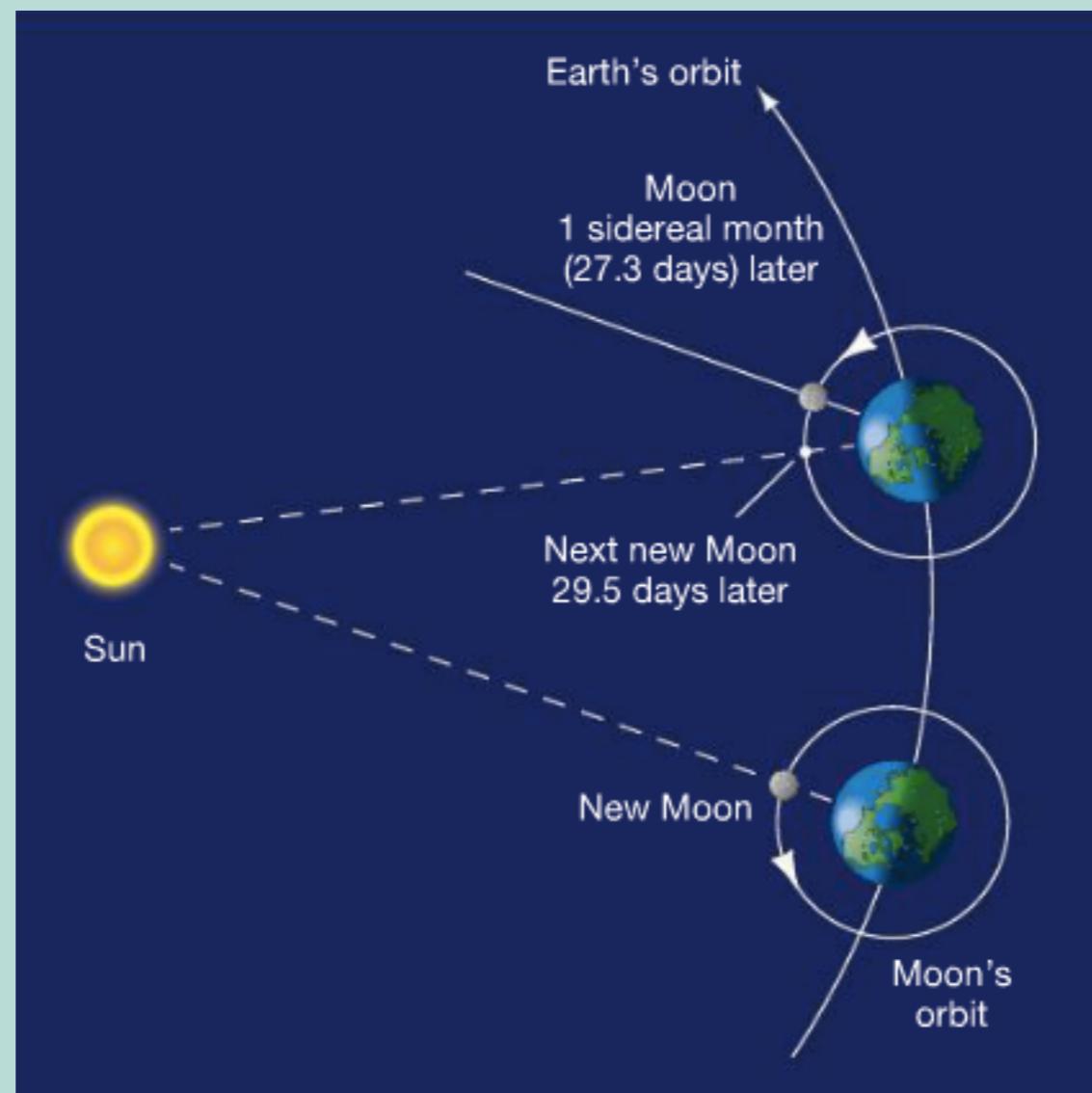
The Moon



29.5 day cycle



Sidereal vs Synoptic month



Eclipses



Annular



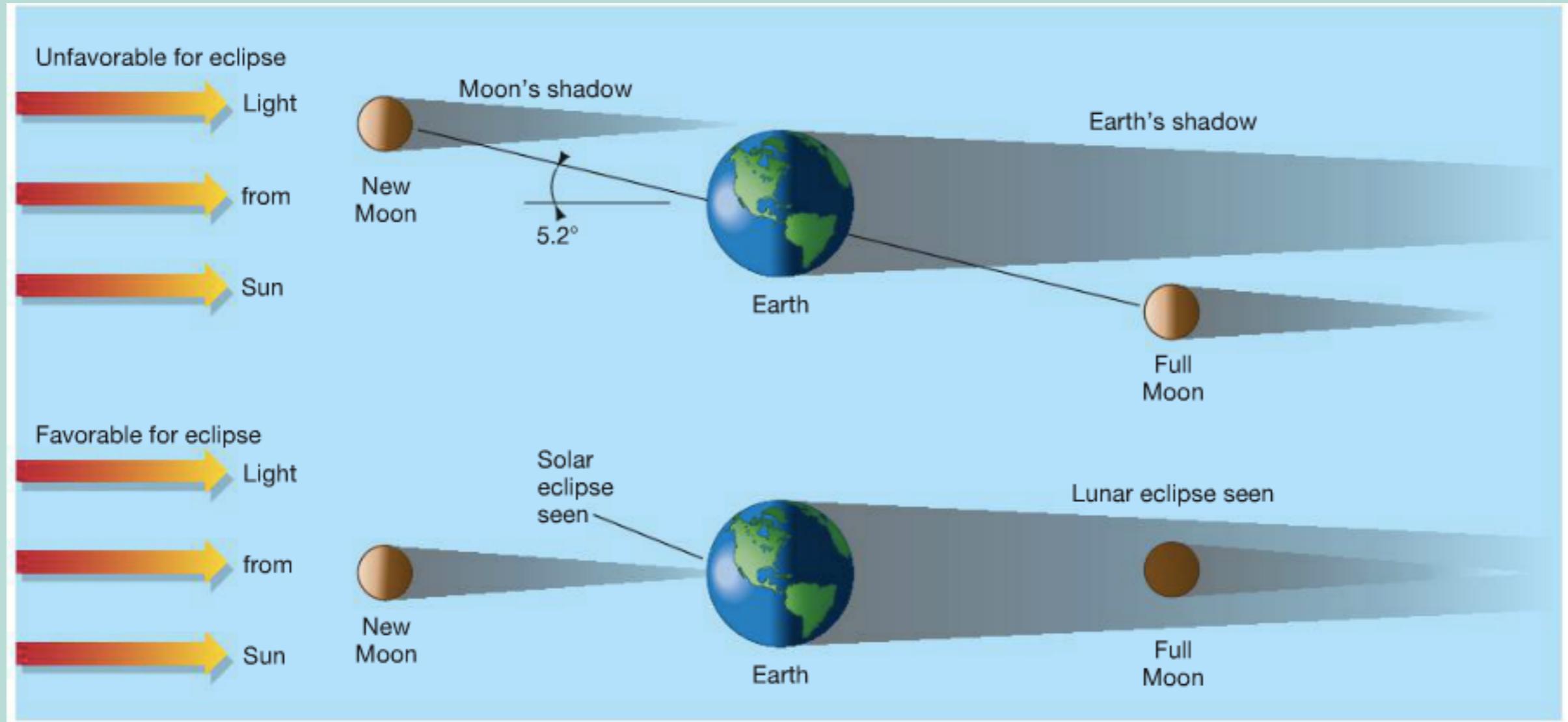
Total

The moon is ~400 times smaller in diameter but 400 times closer than the sun, thus both objects have the ~same angular size, ~.5 degrees

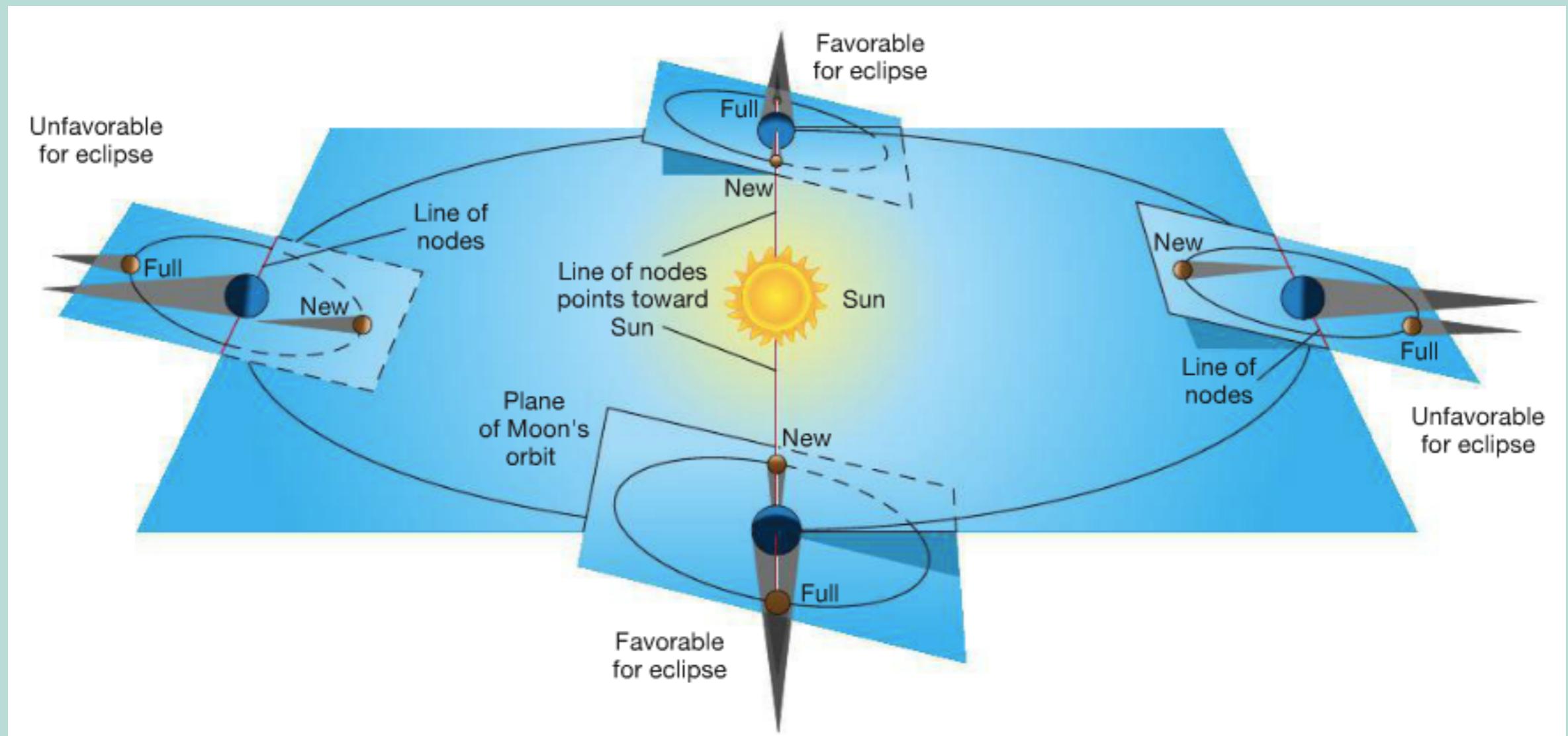
-this is an example of a **syzygy**, easily the best word (need a blank in scrabble)

Why don't eclipses happen once
a month?

Tilt of the moon's orbit with respect to the ecliptic plane



Eclipse Seasons



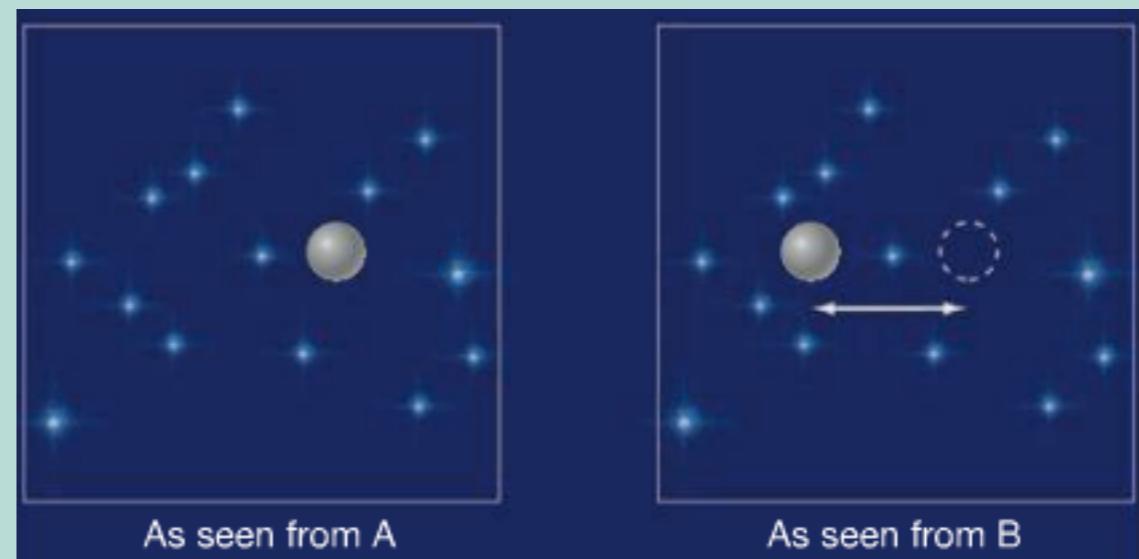
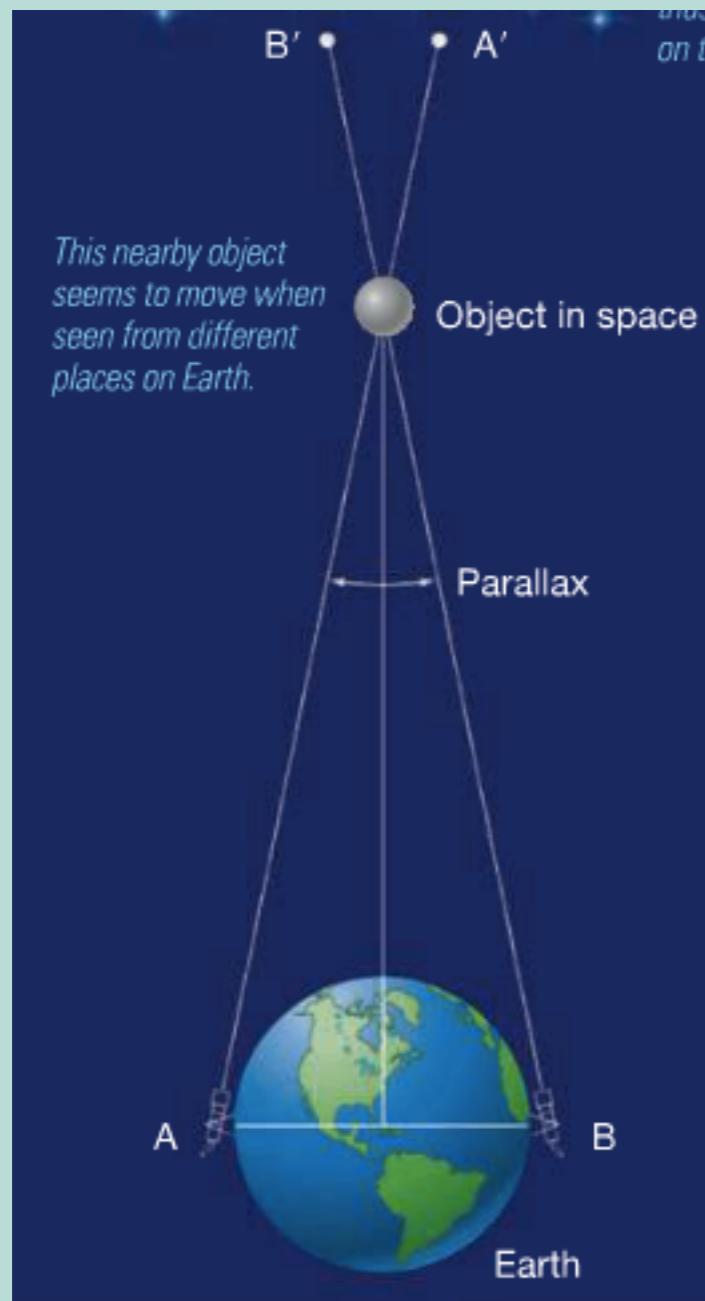
Eclipse Seasons

Just like how gravitational perturbations make the earth's axis precess, the line of nodes precesses as well!

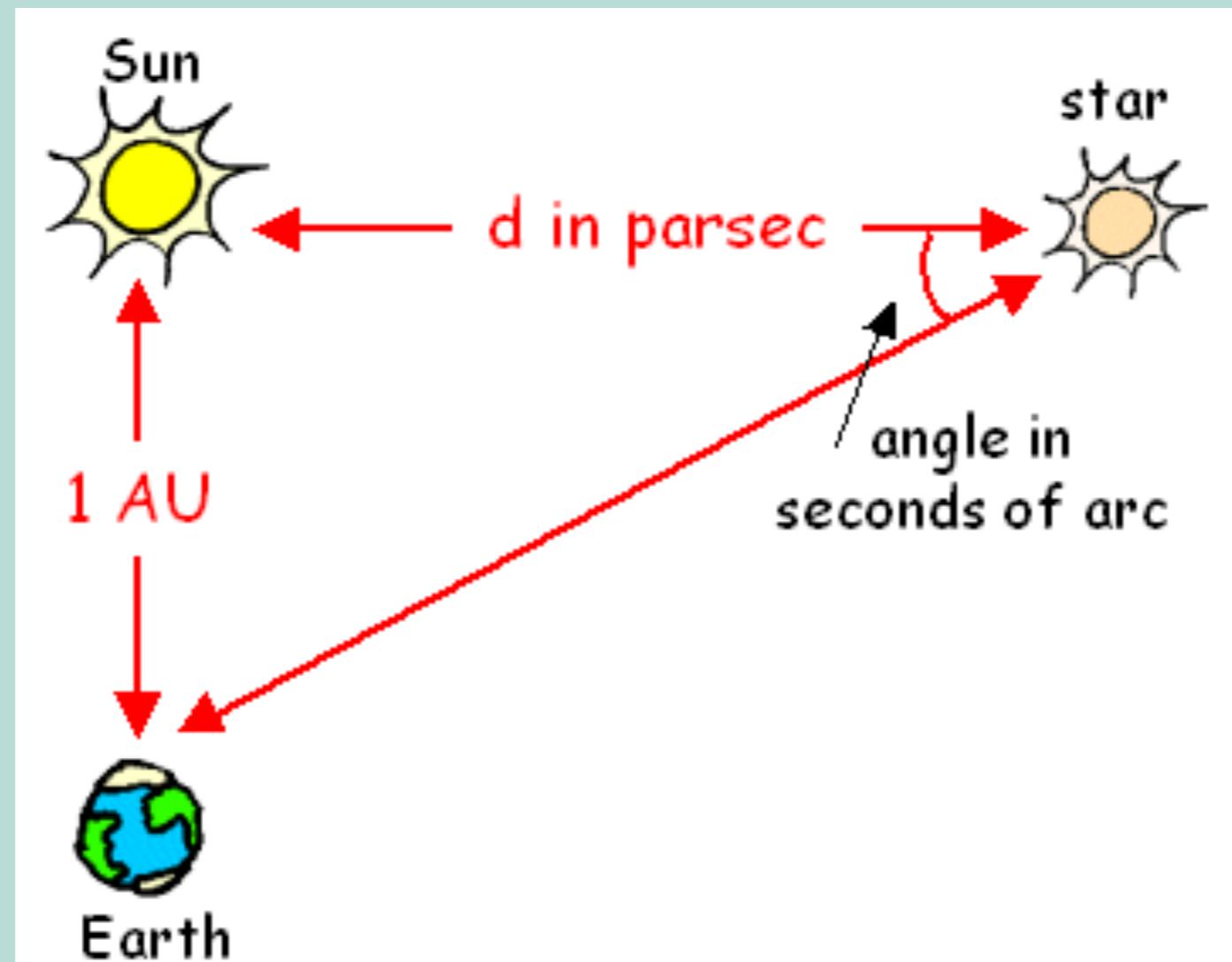
Thus the time between when the line of nodes points to the sun from one year to the next isn't exactly 1 year, but rather
346.6 days = 1 eclipse year

Since 19 eclipse years ~223 lunar months, every 6585 solar days (18 yrs 11.3 days) you see the 'same eclipse'

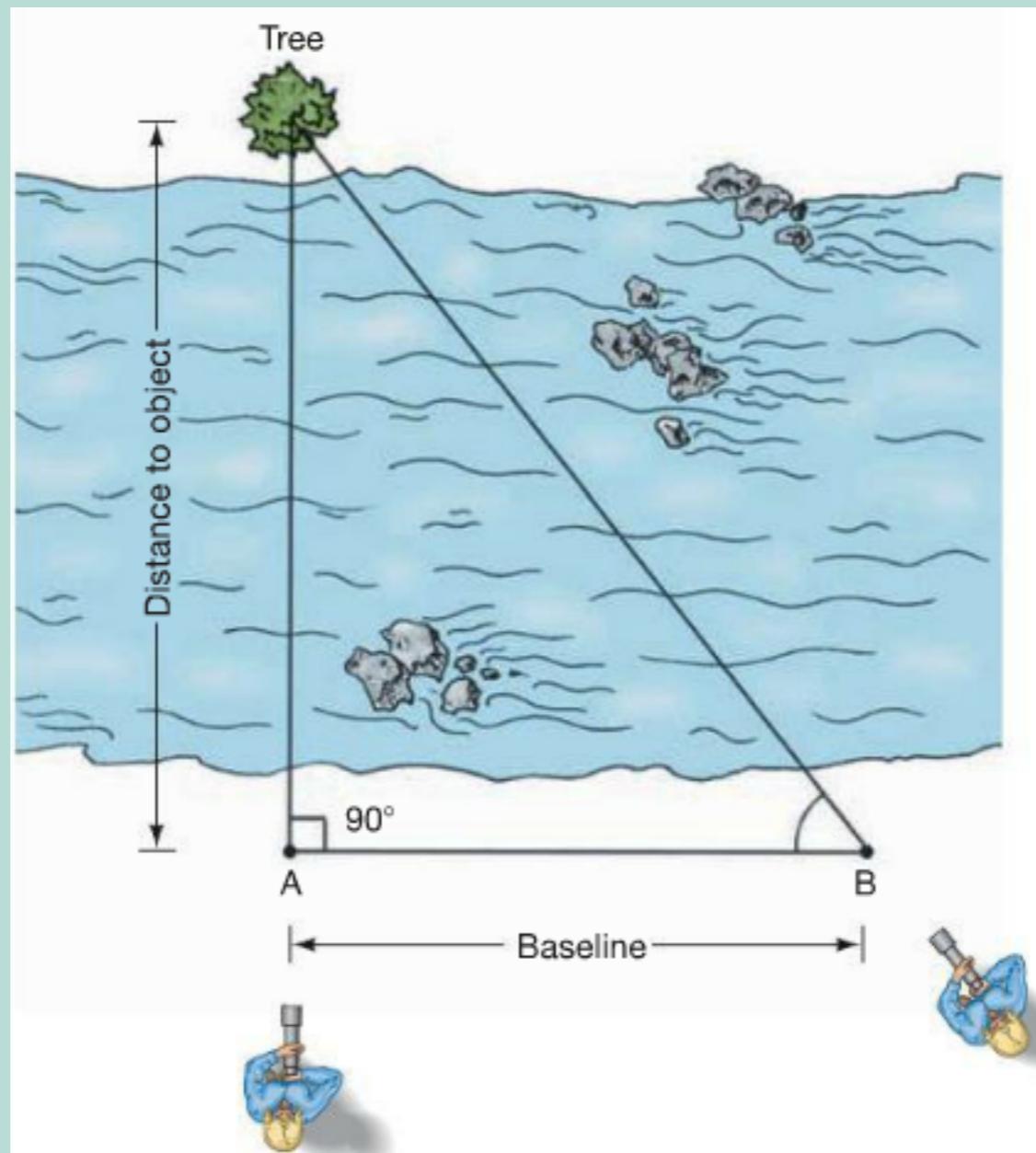
Parallax



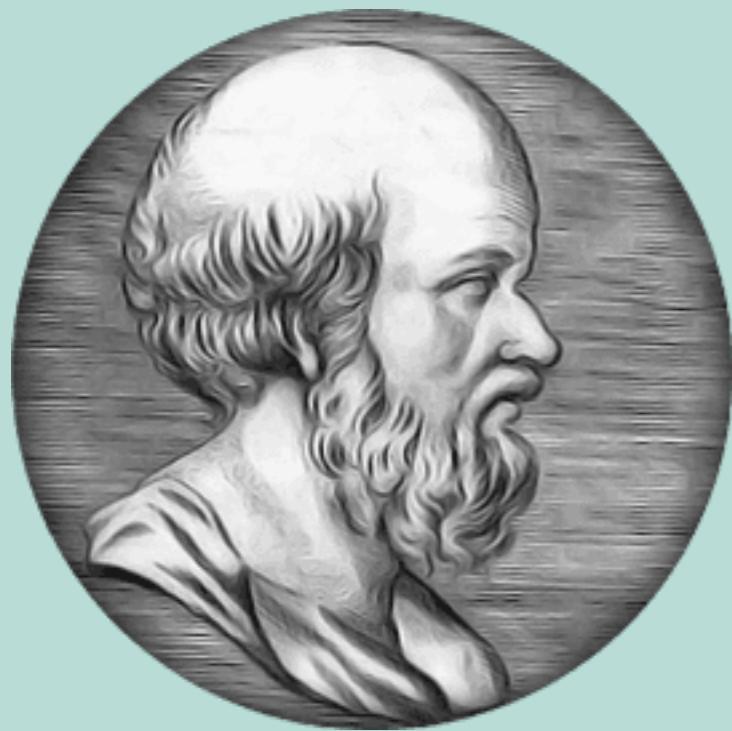
Parallax



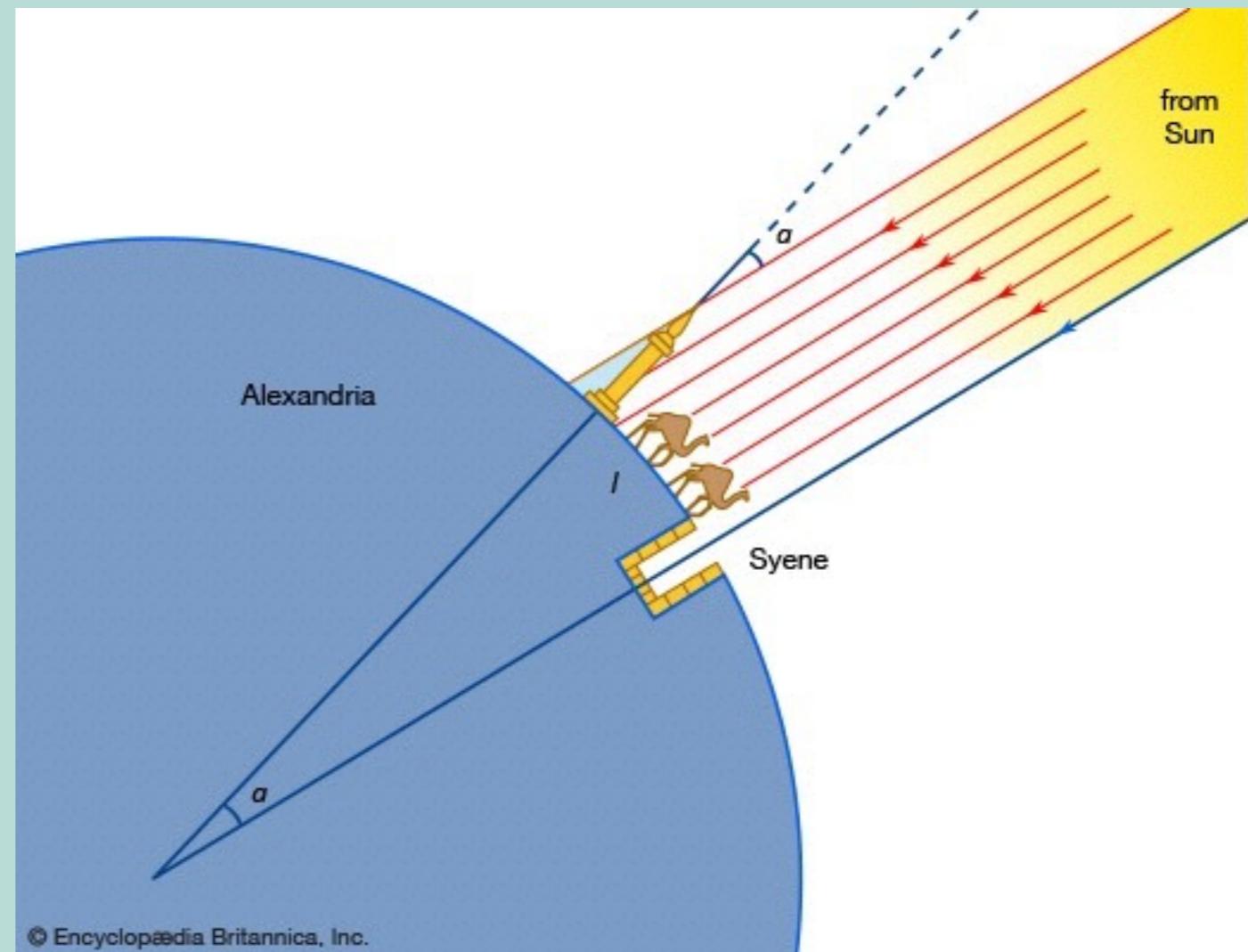
Triangulation



Science Rulez



Eratosthenes
276 BCE-
194 BCE



$$\frac{7.2^\circ}{360^\circ} = \frac{5000 \text{ stadia}}{\text{Earth's Circumference}}$$

$C = 6366 \text{ km}$ (vs true 6378 km)...1% accuracy!!