Chapters 1, 2: Introduction, Earth and Sky

- Orientation to the Universe - sizes and distances
- Frames of Reference: equator, ecliptic, horizon
- The Seasons
- Eclipses of the sun and moon

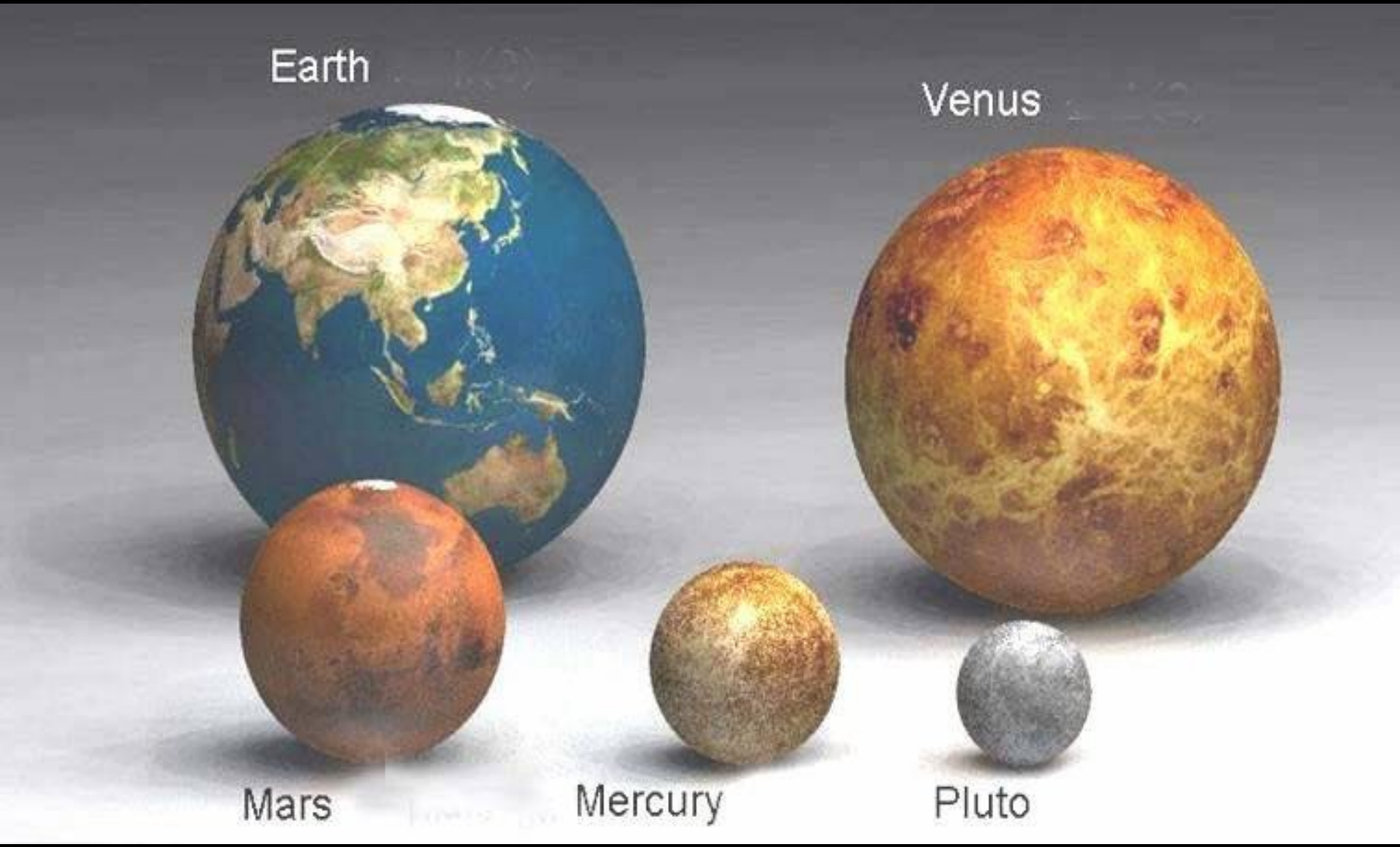
Key Points

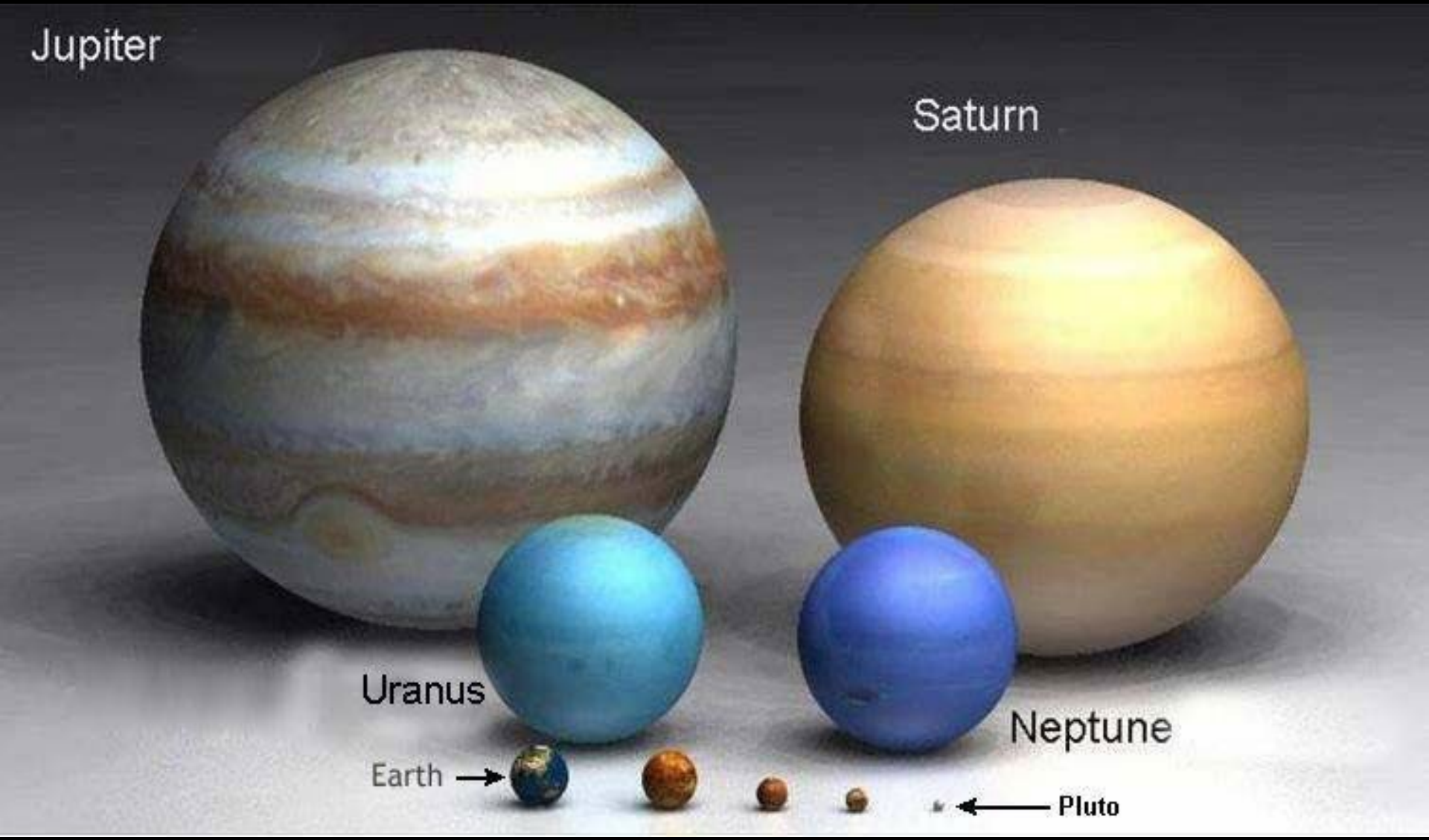
- The most abundant element in Universe: Hydrogen
- Know how the sky looks, how it turns when you are on the Earth's equator, mid-latitudes, and poles.
- Know the seasons and where the sun is during each of them.
- Earth's orbit is elliptical, closest to sun Jan 4, farthest on July 4, but only different by 2%
- Know why summers warmer than winters. Tilt of axis, NOT distance from sun, is what causes temperature seasons
- Lunar eclipses: moon passes into Earth's shadow, always at Full moon phase
- Solar eclipse: moon's shadow cast onto Earth, always at New Moon phase.
- Just know the basic names of the phases of the moon, for reference when we get to tides and eclipses

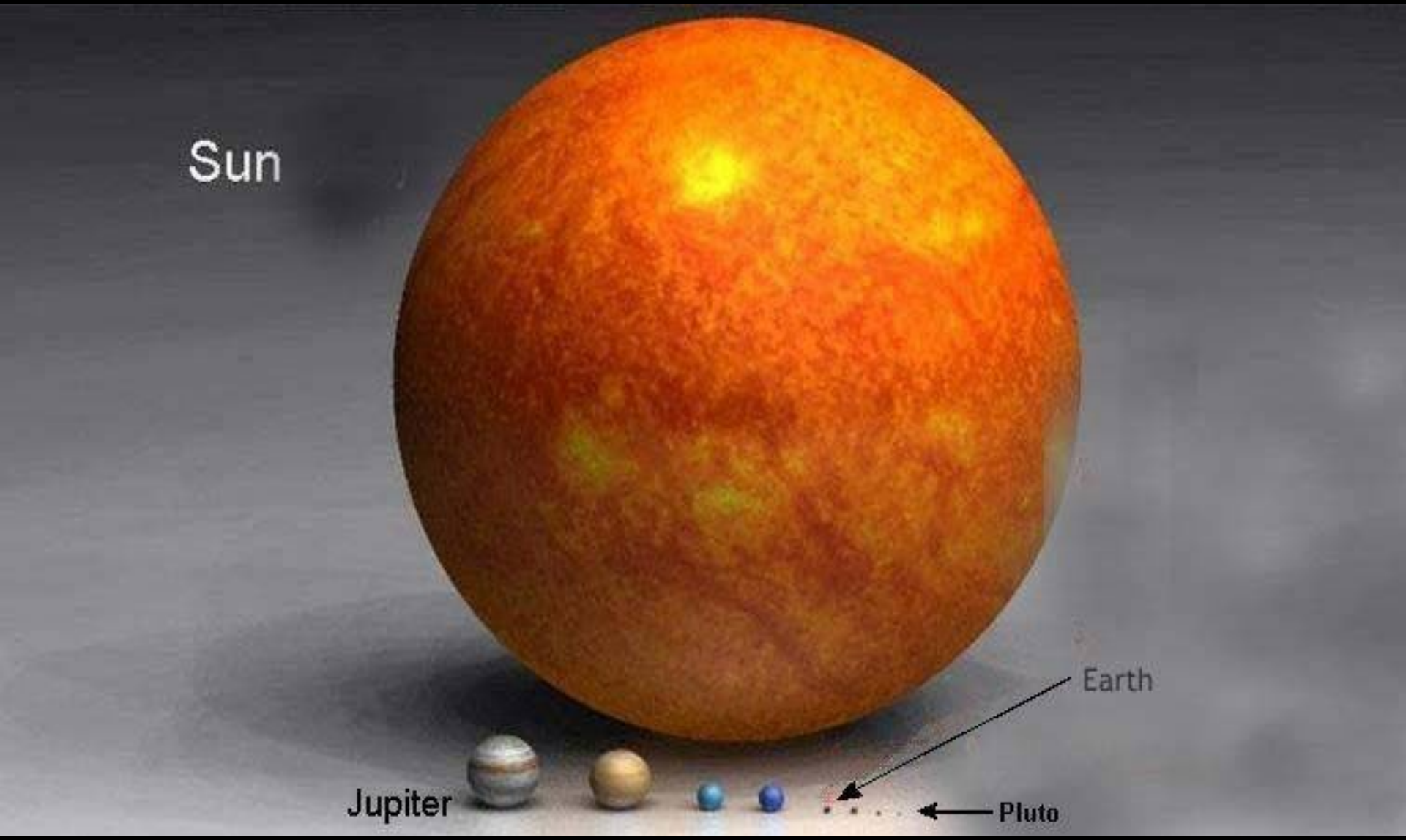
Dimensions, Units

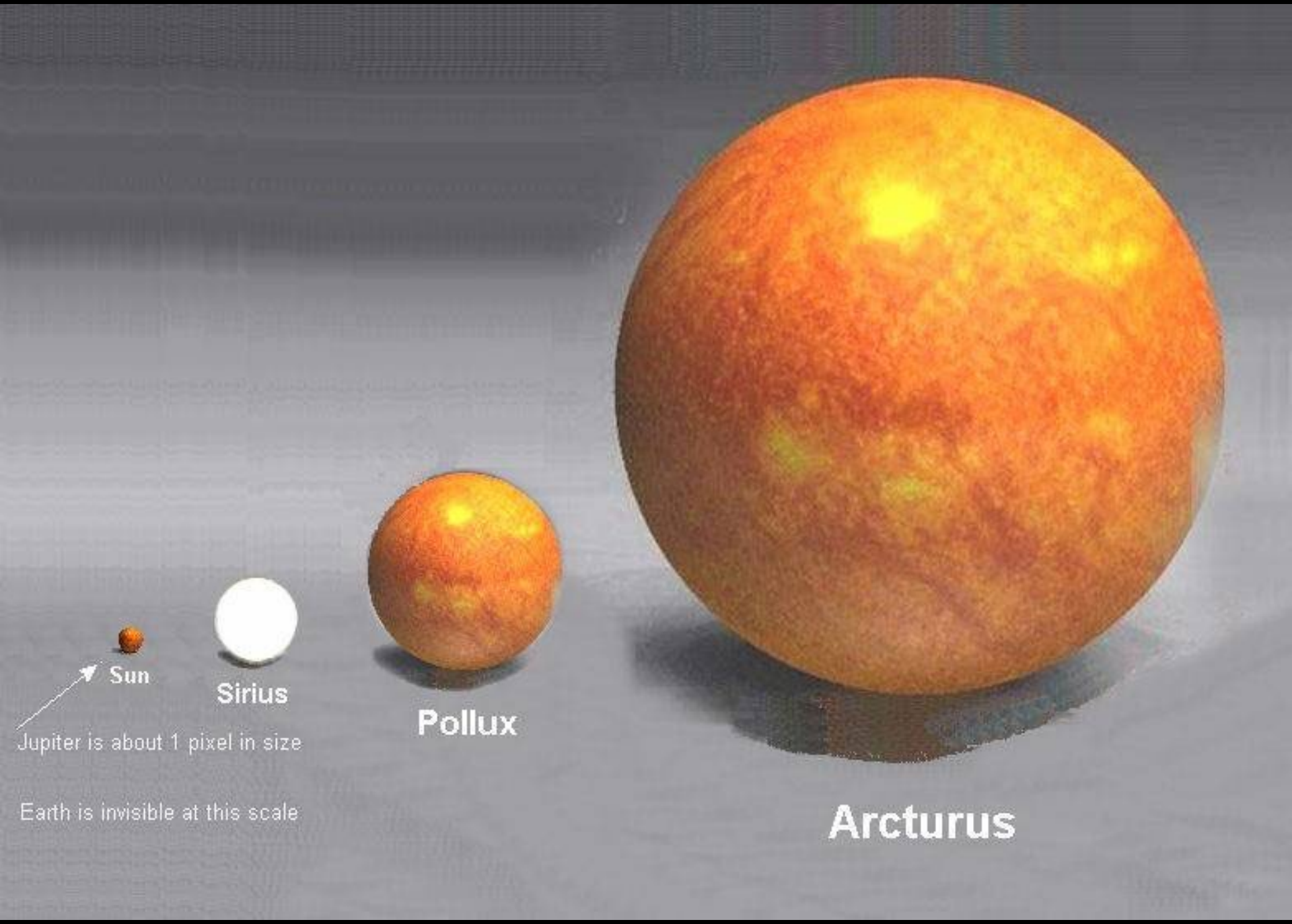
- Distance often given terms of light travel time @ speed of light = 300,000 km/sec
- Moon is 2 light seconds away
- Sun is 8 light minutes away
- "Astronomical Unit" = 1 AU = ~avg distance Earth-to-sun
- Solar system is ~1 light day across
- Nearest star is 4 light years away
- Milky Way Galaxy is ~100,000 light years across
- Andromeda Galaxy – nearest galaxy like our own – is 2 million light years away
- The "observable universe" is 13.7 BILLION light years radius

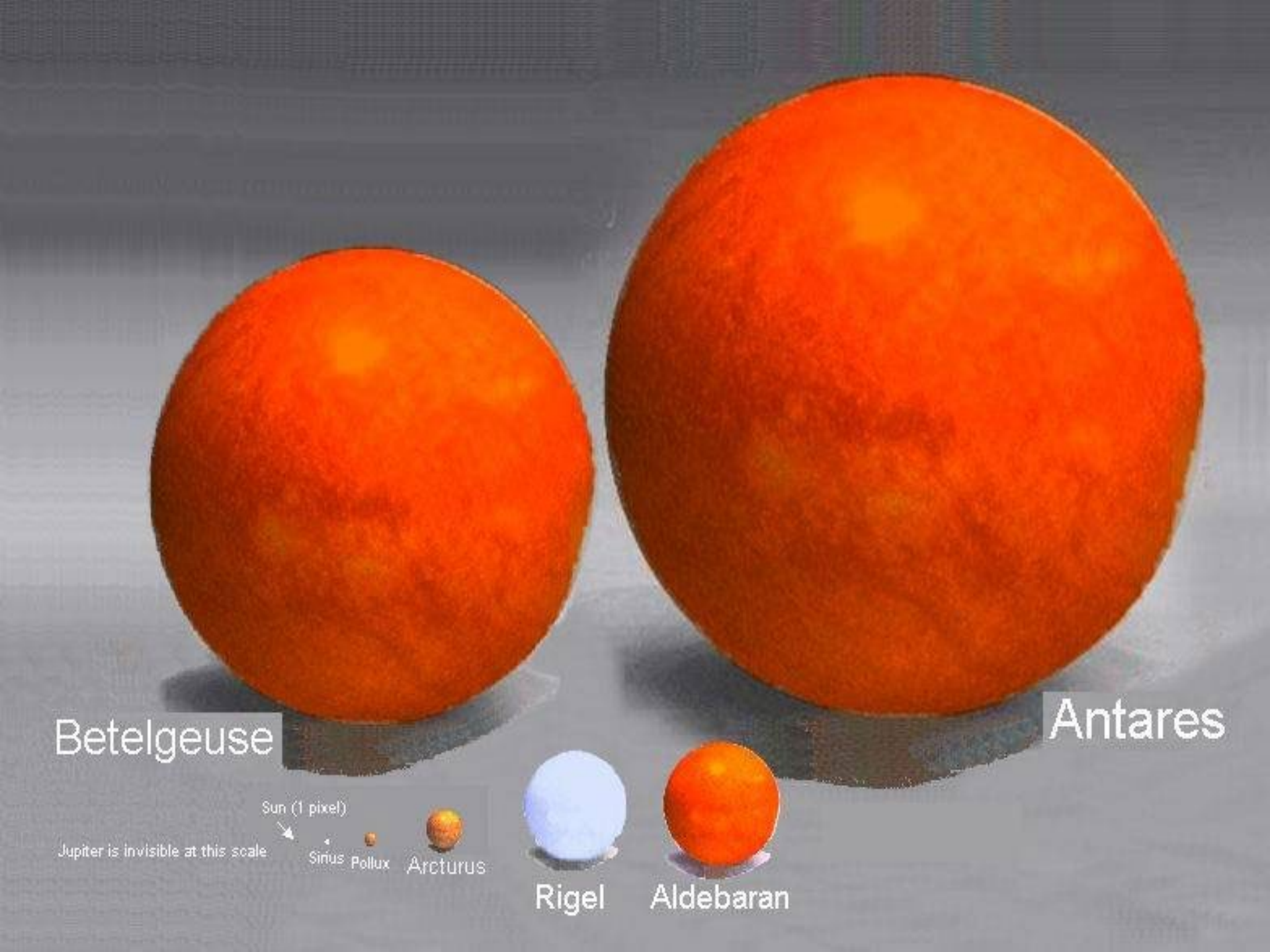
- 1 light year = about 63,241 AU


Earth
Venus
Mars
Mercury
Pluto


Jupiter
Saturn
Uranus
Neptune
Earth
Pluto


Sun
Earth
Jupiter
Pluto


Sun
Sirius
Pollux
Arcturus
Jupiter is about 1 pixel in size
Earth is invisible at this scale


Betelgeuse
Antares
Sun (1 pixel)
Jupiter is invisible at this scale
Sirius
Pollux
Arcturus
Rigel
Aldebaran

And What is *Most* of what we *see* made of…?

- ***Hydrogen!*** = 1 proton and one electron zipping around it. The simplest atom
- 90% of all atoms in the universe are hydrogen atoms
- Don't be fooled… You, me, this room… all are very ***Untypical*** in their chemical composition.

The 4 Forces Governing the Universe

- All (almost all?) natural processes can be described by just **4 fundamental forces of nature**… in order from strongest to weakest:
- **Two Short Range (Nuclear) forces:**
- 1. The Strong Force – (acts between baryons: [protons, neutrons, pions…])
- 2. The Weak Force – acts between certain other elementary particles
- **And Two Long Range Forces:**
- 3. Electromagnetism (acts between charges)
- 4. Gravity (acts between masses)

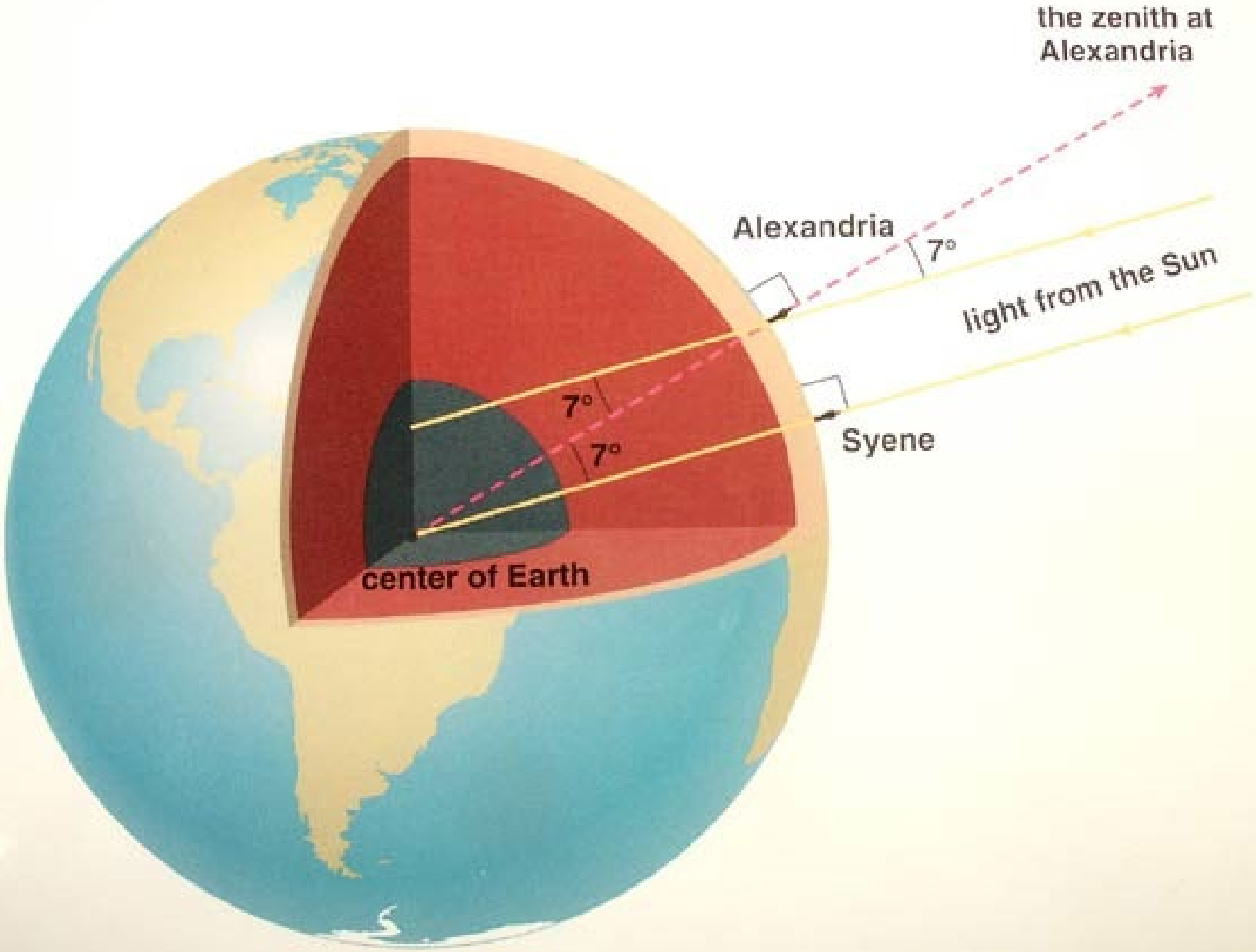
Back to Earth… let's get started

- How does the sky behave, and why?
- What causes the seasons?
- The earth and it's motions and how this affects the sky

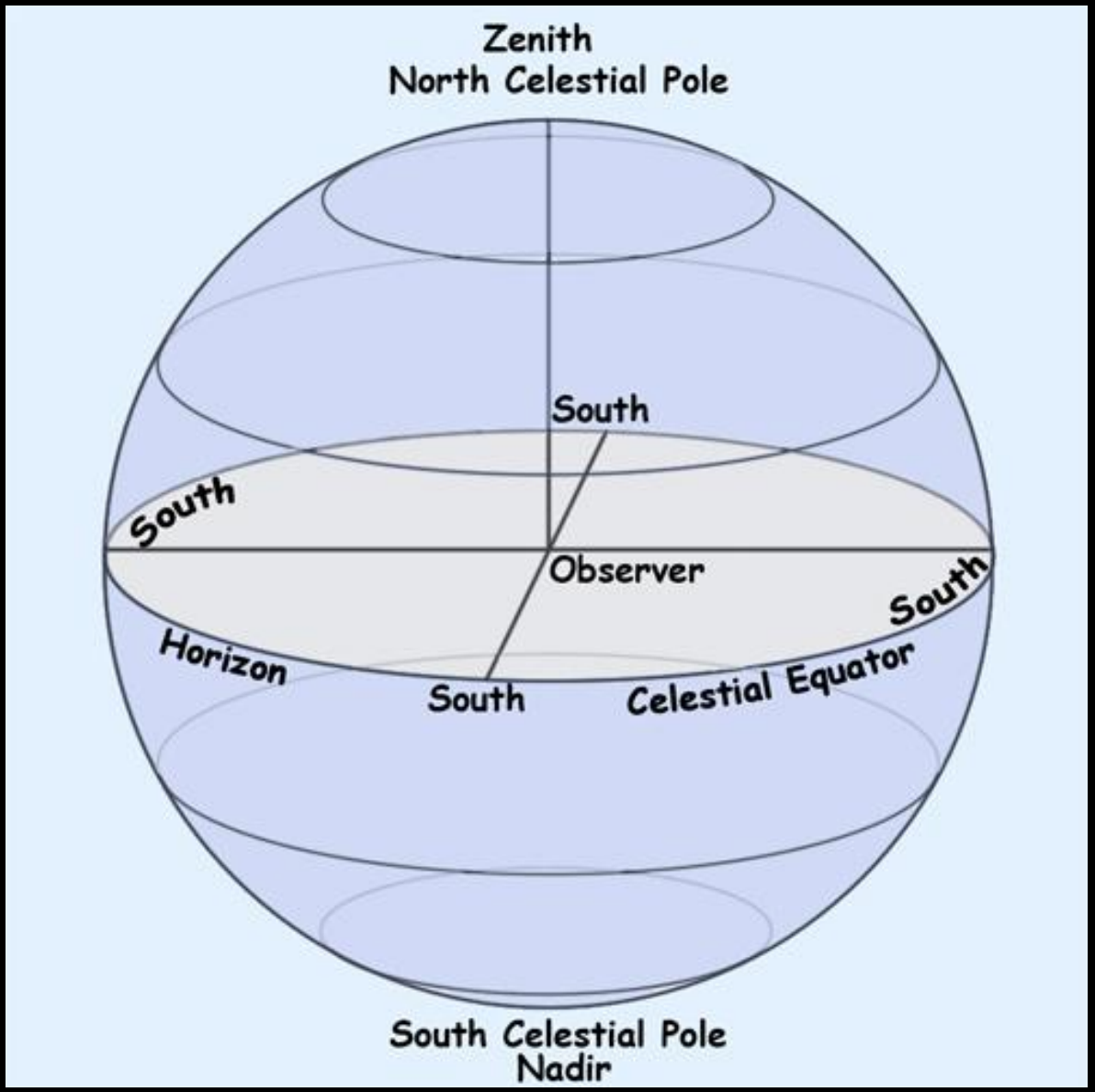
Did all the Ancients figure the Earth was Flat?

- You might think so, but the ancient Greeks figured out it was a sphere. How? By watching eclipses of the moon and noting they always happened 180 degrees away from the sun, and cut a circular shadow regardless of time of day.
- Only one figure cuts a circular shadow no matter how it's turned - a sphere
- They even measured how big it was, correctly! Way back in ~250BC. Eratosthenes did this.

Figure 3.13 Method of Eratosthenes

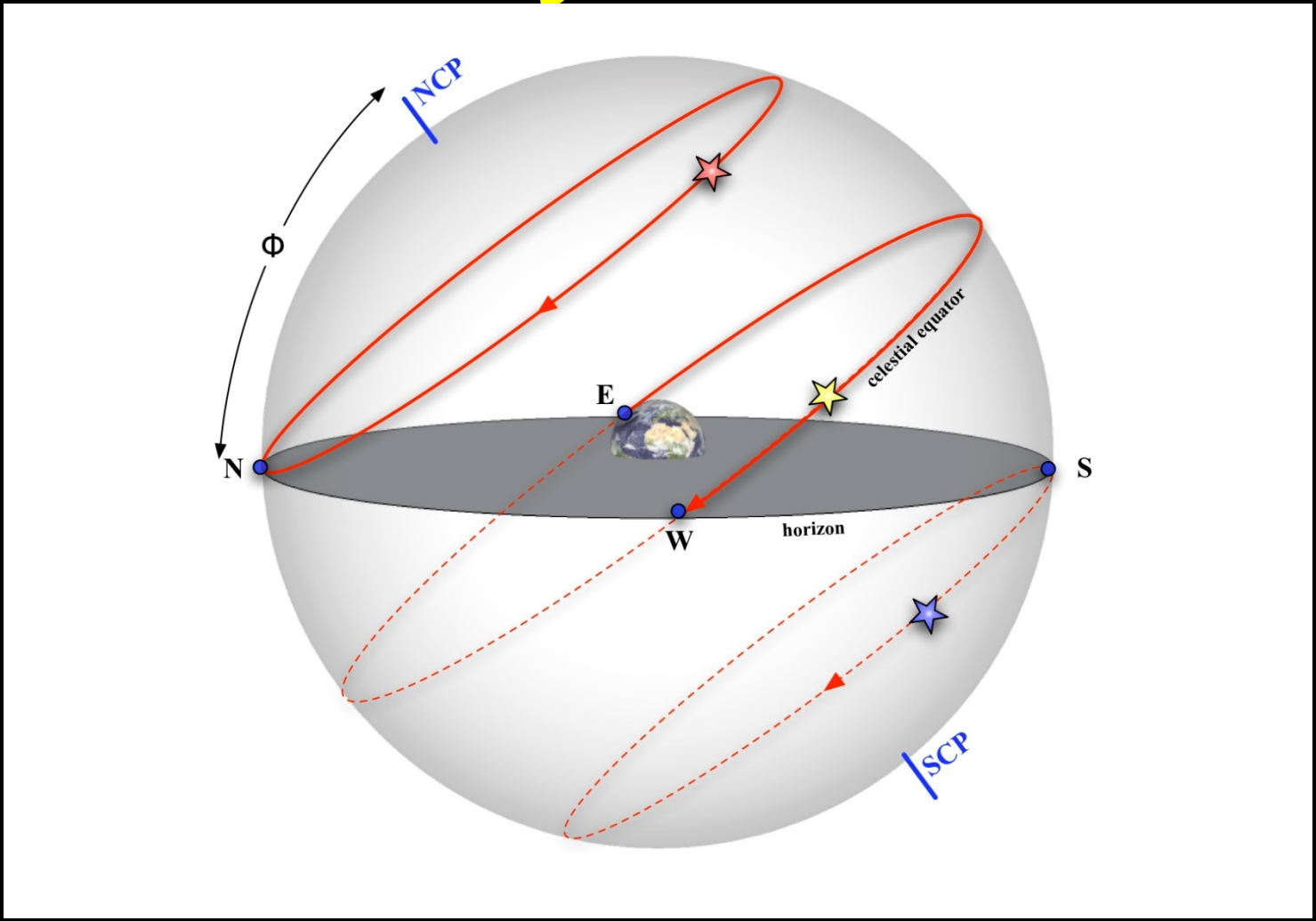


Looking straight up from the North pole. The stars would just spin in a circle centered directly overhead, and so no stars rise or set, but instead circle parallel to the horizon

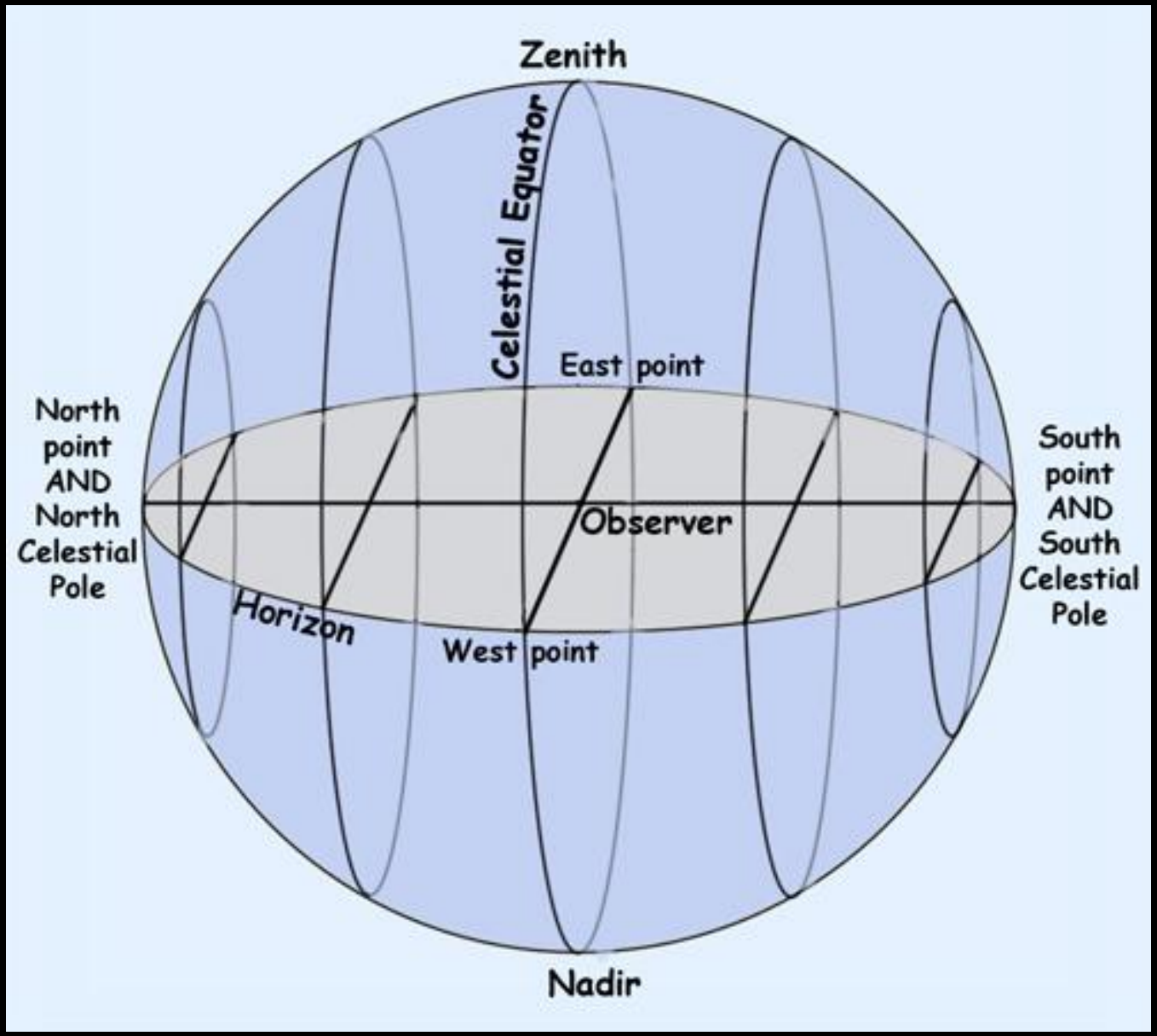


The North Celestial Pole here is straight overhead, so all stars just move sideways, neither rising nor setting.

From mid latitudes like Santa Cruz, the stars move across the sky like this



And from the equator, stars and the sun and moon rise straight up and go straight down




© www.danheller.com

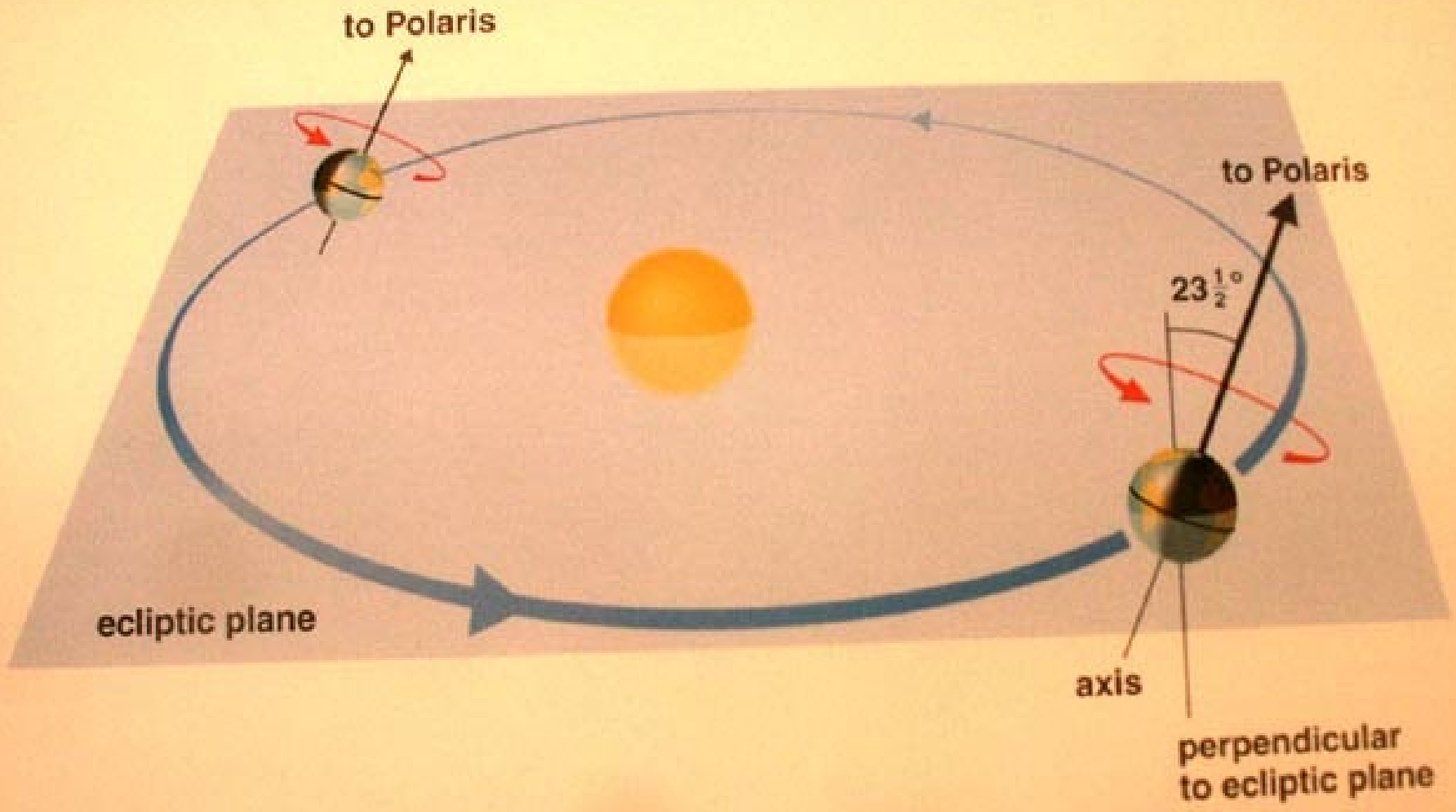
Where do you Suppose that last slide's photo was taken from?

- Here's the reasoning…
- There's a bright'ish star where the stars are circling around. There is no "south star", only a "North Star", and that must be it.
- That star is very close to the north celestial pole, which is directly overhead at the Earth's north pole.
- But here's it's just above the north horizon so we must be only a degree or two north of the equator.
- Maybe Equador? Peru? Indonesia? Maybe Mt. Kilaminjaro in Kenya?

The Seasons

- Primary cause – Earth's **rotation axis** is tilted relative to **orbital axis**
- Why warmer in summer?(1) more daylight hours, and (2) daytime sun is higher in the sky
- Earth's orbit is nearly a circle: 92 million miles at closest, 94 million at farthest – conclusion: not much, and so doesn't affect annual temperatures much
- At Santa Cruz latitude, distance only makes 4% difference in heating, while seasonal effect is a factor of 2; *i.e.* much larger.

Figure 1.18 Inclination of Earth's axis

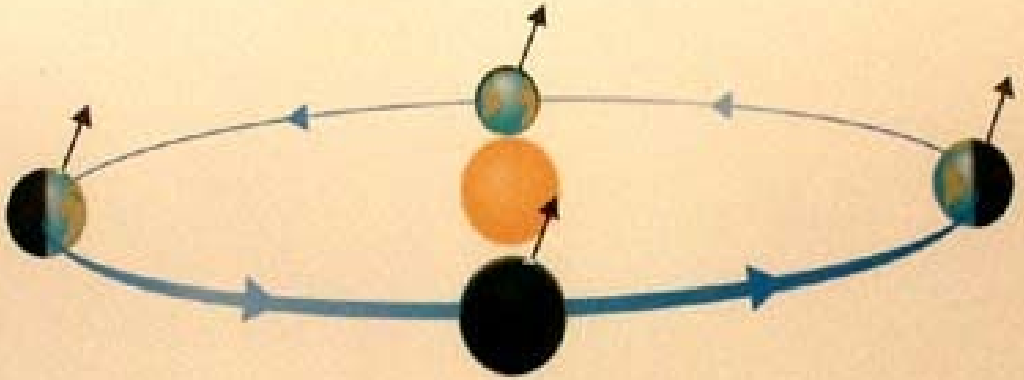


Solstices and Equinoxes

- ***Equinox*** – “Equal periods of Night”. Everywhere gets 12 hours of daylight, 12 hours of night.
- ***Solstice*** - “sun stands still”. The sun has reached farthest north or south of the celestial equator, and reverses direction.
- ***Winter Solstice***: Dec 21. Sun is farthest south, 23 degrees south of the celestial equator
- ***Spring Equinox***: Mar 21. Sun crosses the celestial equator heading north
- ***Summer Solstice***: June 21. Sun is farthest north, 23 deg north of the celestial equator
- ***Fall Equinox***: Sept 21. Sun crosses the equator heading south.

Figure 1.19 The cause of the seasons

1. Spring Equinox
Spring begins in the Northern Hemisphere, fall in the Southern Hemisphere.

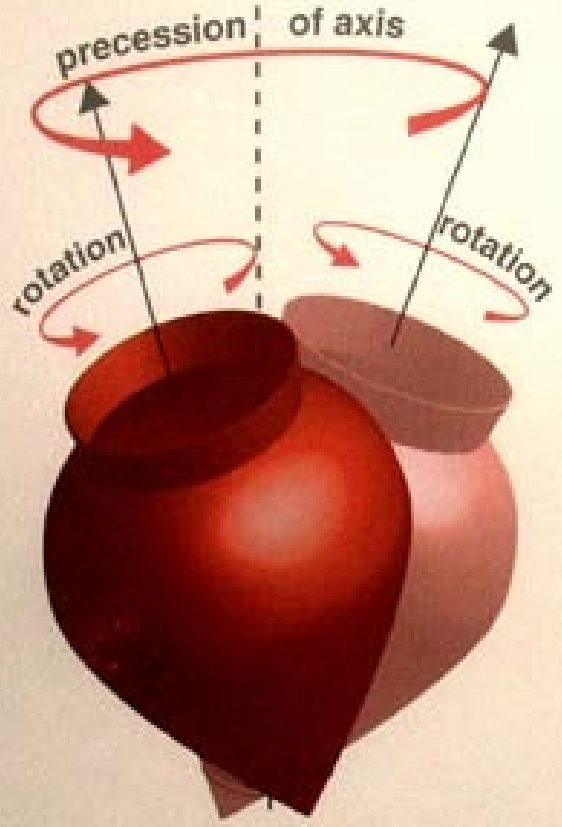


2. Summer Solstice
Summer begins in the Northern Hemisphere, winter in the Southern Hemisphere.

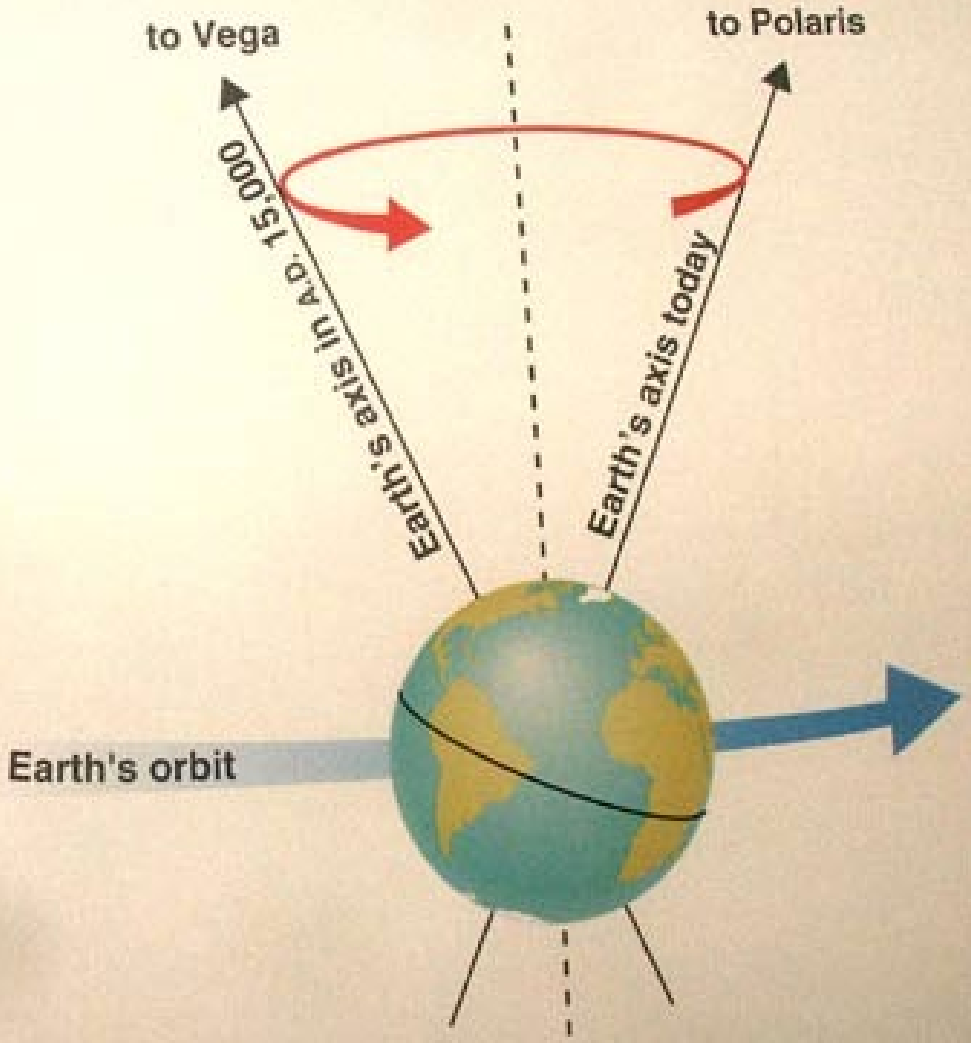
4. Winter Solstice
Winter begins in the Northern Hemisphere, summer in the Southern Hemisphere.

3. Fall Equinox
Fall begins in the Northern Hemisphere, spring in the Southern Hemisphere.

Figure 1.20 Earth's precession



a



b

Axis Tilt, not Distance to Sun, Causes Seasonal Temperature Differences

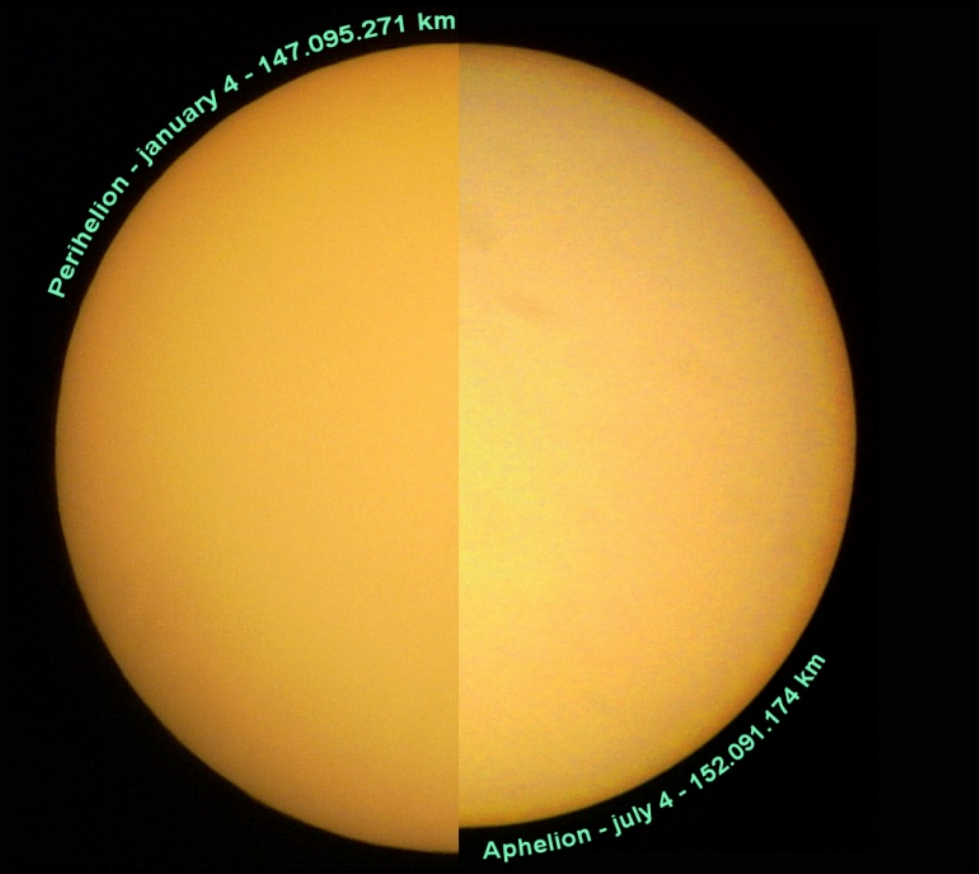
- Common misconception – sun is "farther" in winter, "closer" in summer. Nope!
- Earth's orbit IS elliptical and distance to the sun does vary, but not by much; 91.9 million miles *vs* 94 million miles.
- How much would you expect this would affect temperatures? (follow Rick on the white board)

Interesting Facts:

- We're **closest** to the sun on **January 4th**
- We're **farthest** from the sun on **July 4th**

(plus or minus a day or two because of leap year)

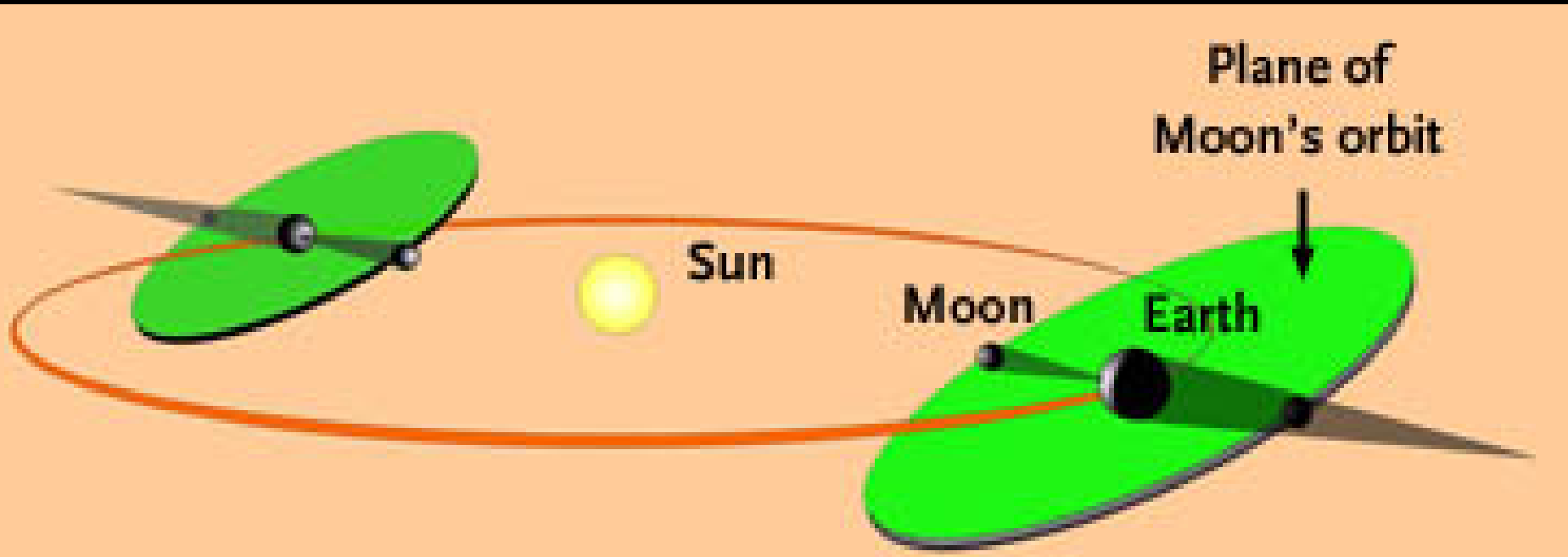
Here's the difference between the perihelion and aphelion angular size of the sun in the sky. Not much…



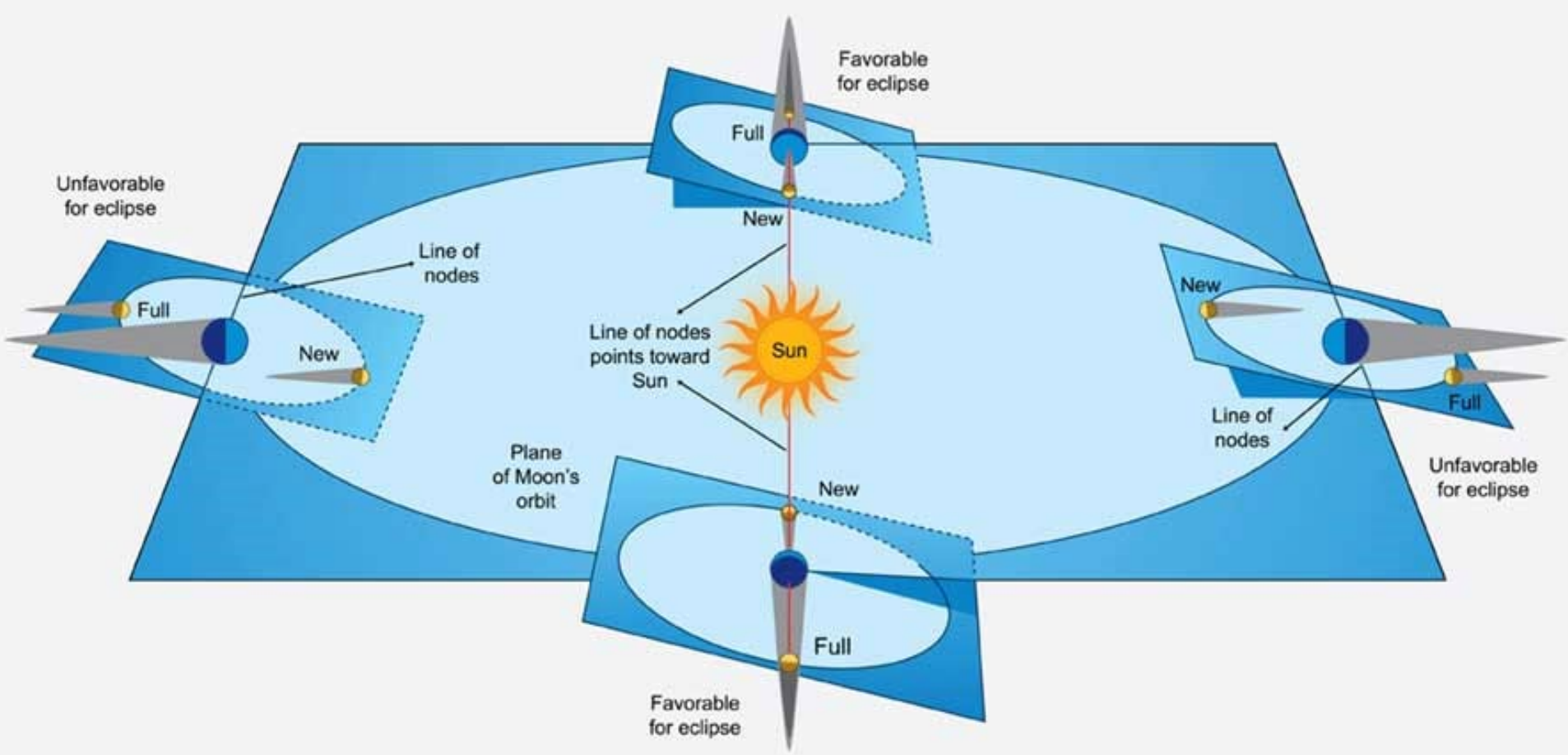
Eclipses of the Sun and Moon

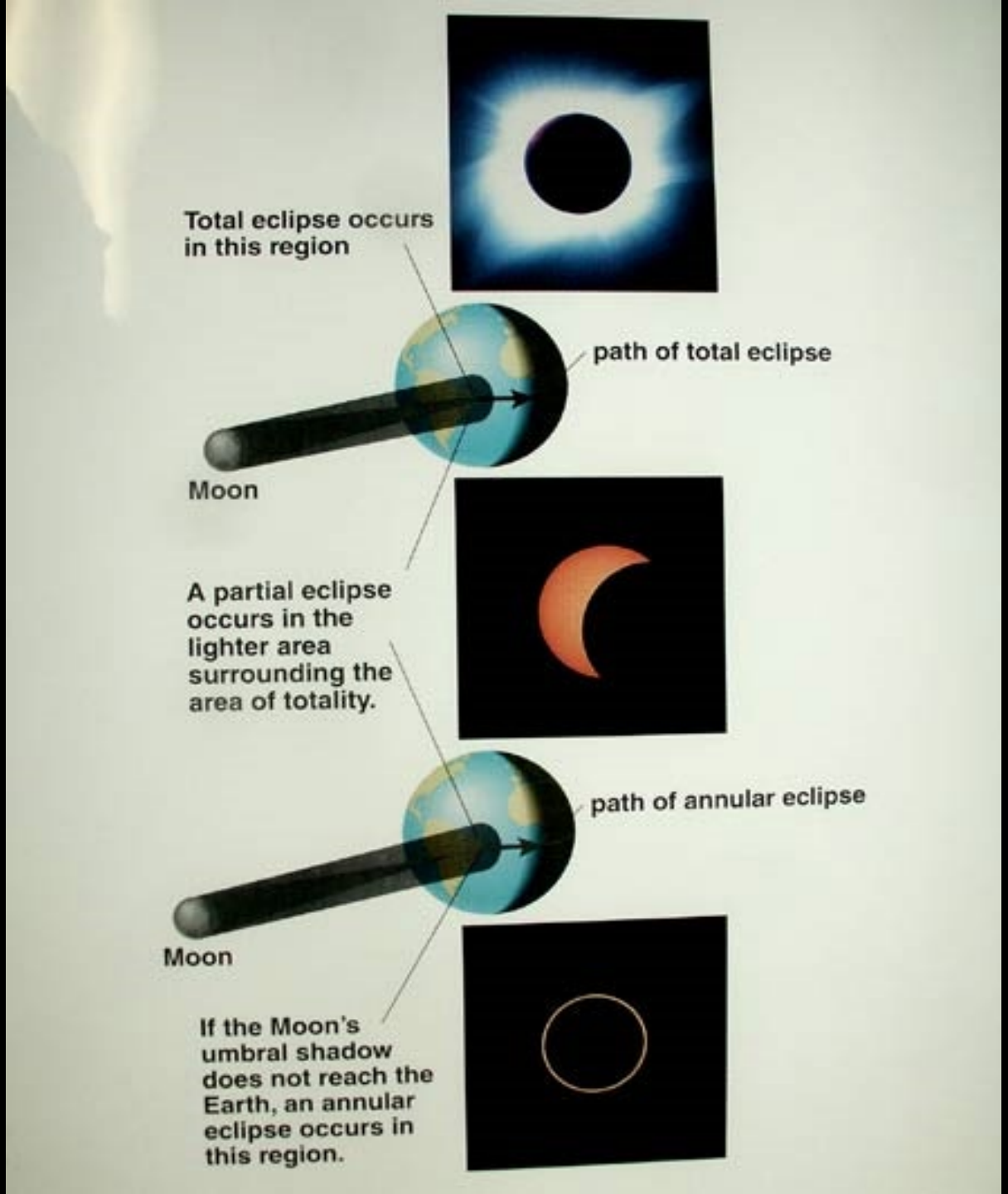
- Eclipses happen when earth's shadow follows on the moon (Lunar Eclipse), or moon's shadow falls on the earth (Solar Eclipse).
- How would this affect when/if eclipses happen?

The “line of nodes” is where the moon’s orbital plane intersects the Earth’s orbital plane. When that line points towards the sun, we get eclipses.



Since the sun and moon are both ½ degree across, the line up doesn't have to be perfect to still get an eclipse, so the "eclipse seasons" last fully 22 days, on opposite sides of the year. So we always get both a solar and lunar eclipse at each.eclipse season



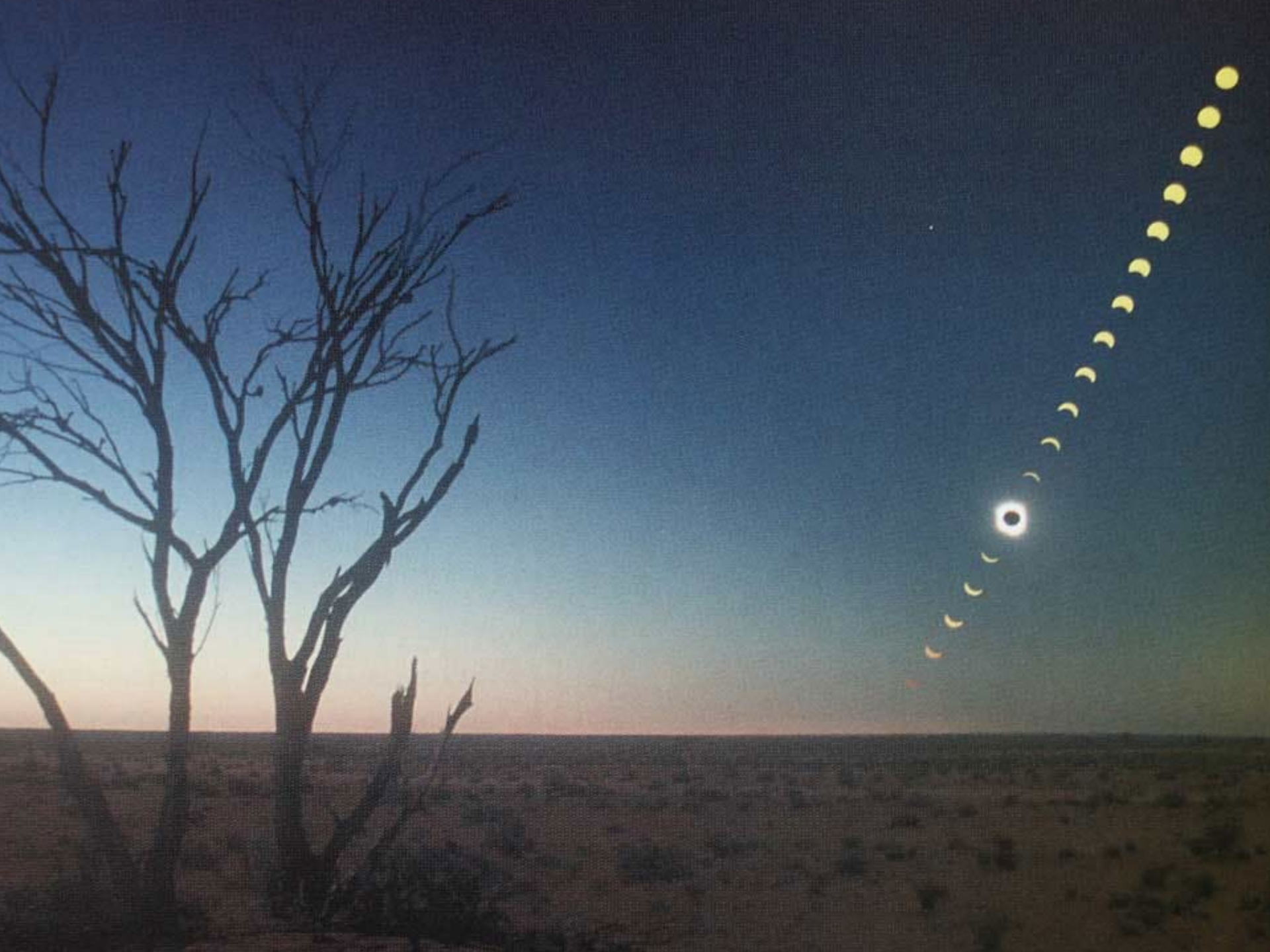


The moon's orbit is elliptical so it's angular size varies too. When the moon's smaller than the sun, we get an annular eclipse

Ponder what are the circumstances which would make for the largest annular ring of sunlight during an annular eclipse.

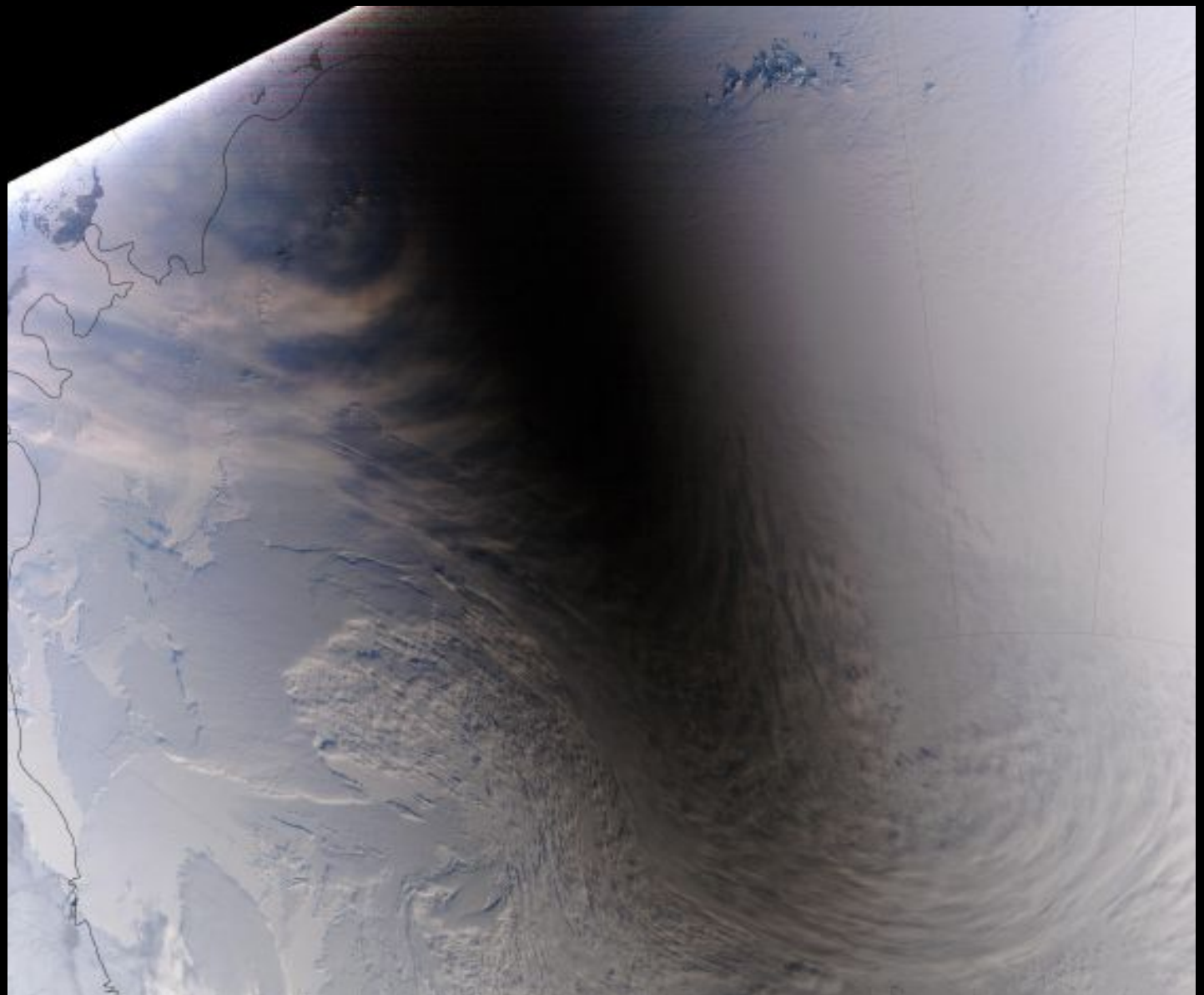
- How far or close should be the sun? The moon?
- What day would you need for the eclipse?
- What time of day would add a bit more to the extreme we seek?

Another rather extreme annular solar eclipse. The moon is quite a bit smaller angular size vs. the sun.

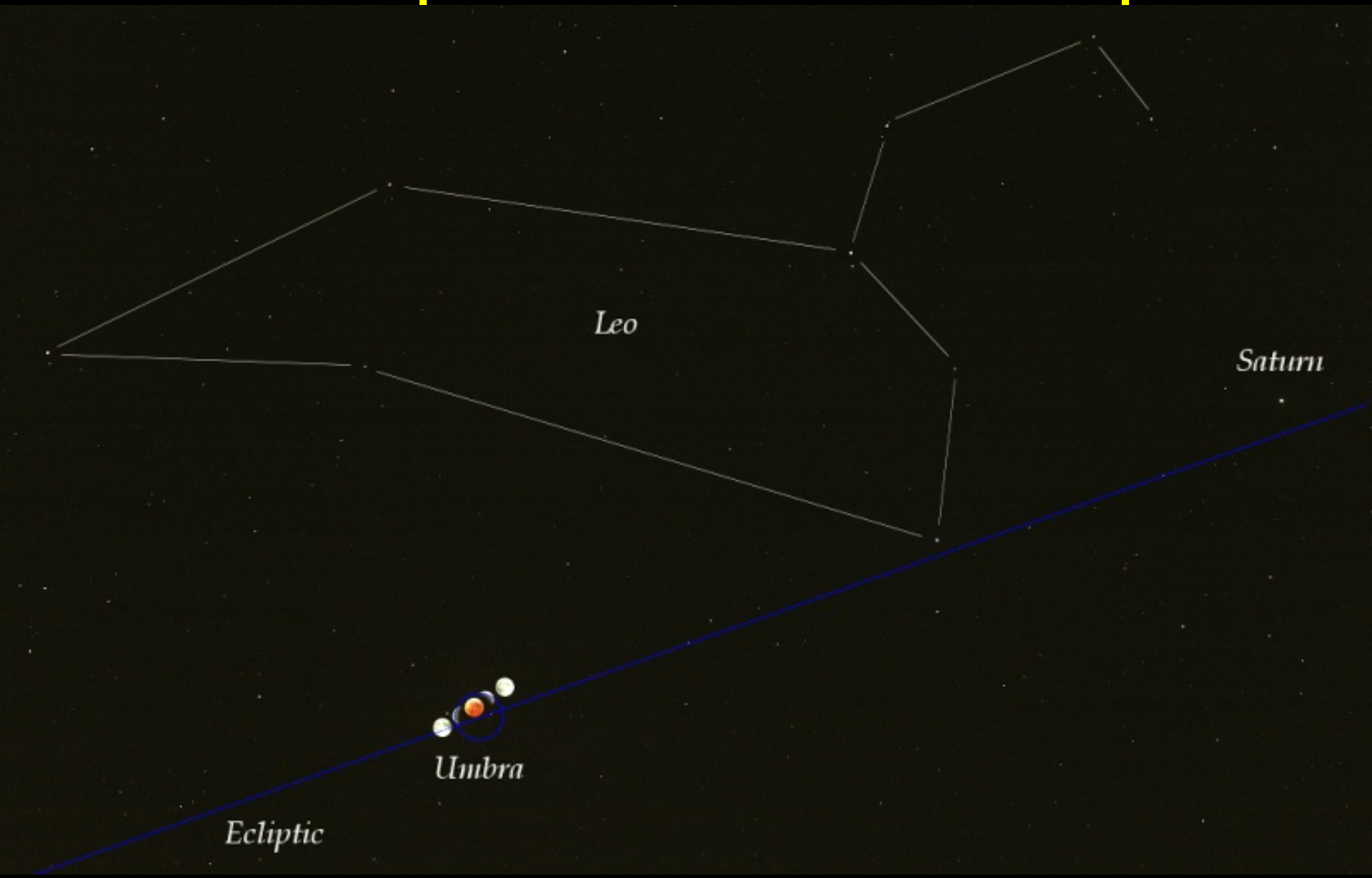


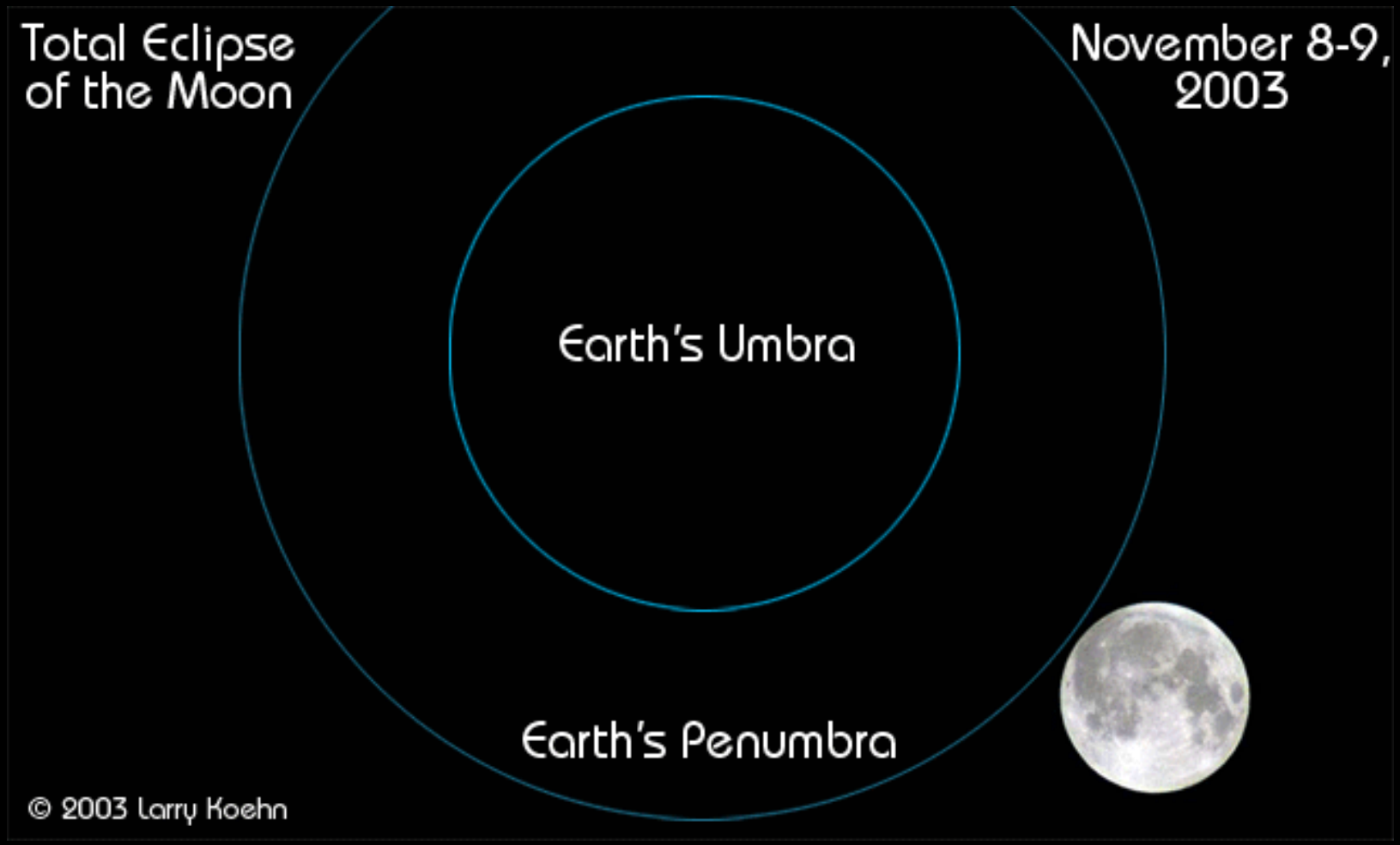
Solar Totality from Space

Antarctic Eclipse, grazing shadow geometry



Time Lapse Total Lunar Eclipse




Total Eclipse
of the Moon
November 8-9,
2003
Earth's Umbra
Earth's Penumbra
© 2003 Larry Koehn

Penumbral Lunar Eclipse
Moon passes through penumbra.

Partial Lunar Eclipse
Part of the Moon passes through umbra.

Total Lunar Eclipse
Moon passes entirely through umbra.

he Royal Astronomical Society of Cana-
duced this montage of the April 24th
m images taken with an 8-inch Meade
anon A75 digital camera. It shows the
through the penumbra — the pale outer
from west (right) to east. "There was a
on in my last shot," says Tuomi.

www.MrEclipse.com

What would you see if you were on the moon during a total lunar eclipse?

- You'd see sunset orange glow around the whole circle of the Earth (which would be 4x the angular size as our full moon in our own sky.
- This glow would be very bright, and light up the ground around you on the moon to a dull orange.
- Still, the brightness of the totally eclipsed moon is only 1/10,000 as bright as the normal full moon

This is what it looks like during a lunar eclipse if you're on the moon

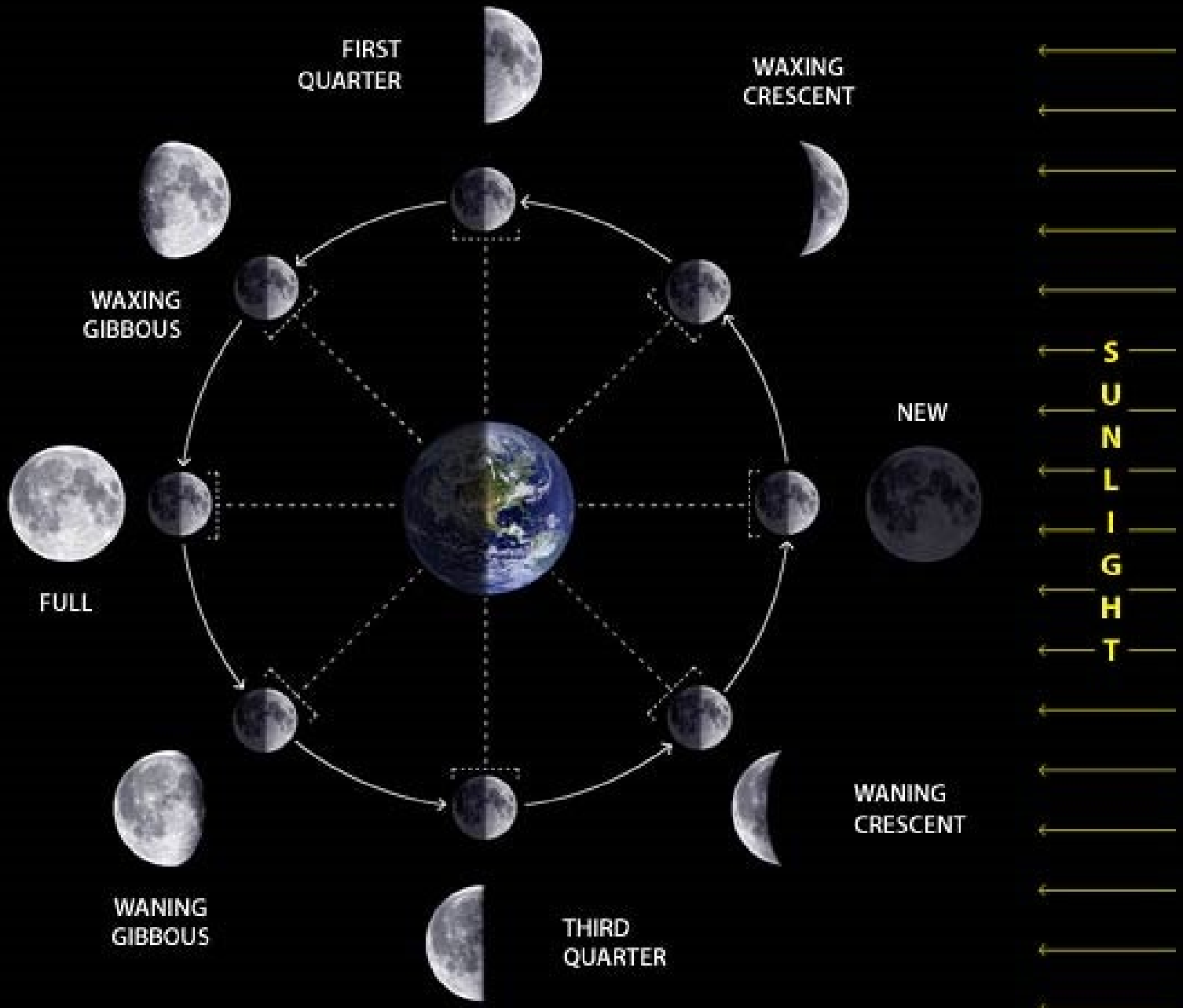
Varying shadow colors as sunlight refracts through Earth's atmosphere to hit the totally eclipsed moon

The bright double star Alpha Librae and the totally eclipse moon

Only the Earth Gets Such Beautiful Eclipses – Because the Moon and Sun, by luck, are the same angular Diameter. Here's a Solar Eclipse on Mars, by Phobos

The Phases of the Moon

- Half the moon is always sunlit and half always dark, obviously.
- But the amount of the sunlit side we see varies as the moon orbits the Earth
- Full moon – when it's opposite the sun and so it's fully sunlit. New moon when it's in the same direction as the sun so the dark side faces us



How do the Moon's phases look, from high above the Earth/Moon system, compared to here on the ground?

- This link tells all! Very nice.

http://aa.usno.navy.mil/graphics/Moon_movie.gif

The Phases of the Moon

These 3 quantities are related. Given any two, you can ponder and see what the third must be

1. The phase of the moon
2. The time of day
3. The place of the moon in the sky

This used to be one of my favorite quiz questions! Teaching it online, is too hard, so I'm not using it this year.

This Photo is a Tease! We'll Discuss in Chapter 4

Chap 2 – Earth and Sky; Key Points

- The most abundant element in Universe: Hydrogen
- Know how the sky looks, how it turns when you are on the Earth's equator, mid-latitudes, and poles.
- Know the seasons and where the sun is during each of them.
- Earth's orbit is elliptical, closest to sun Jan 4, farthest on July 4, but only different by 2%
- Know why summers warmer than winters. Tilt of axis, NOT distance from sun, is what causes temperature seasons
- Lunar eclipses: moon passes into Earth's shadow, always at Full moon phase
- Solar eclipse: moon's shadow cast onto Earth, always at New Moon phase.
- Just know the basic names of the phases of the moon, for reference when we get to tides and eclipses