

Astronomy 210

Section 1 – MWF 1500-1550

134 Astronomy Building

This Class (Lecture 3):

Lunar Phases

Check Planetarium Schedule

HW1 Due Friday!

Next Class:

Early Cosmology

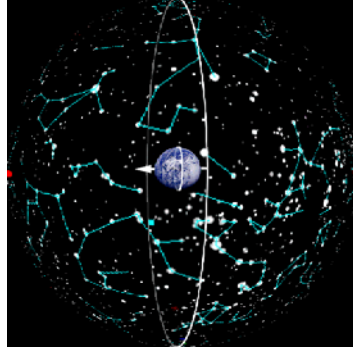
Music: *We only Come out at Night* – Smashing Pumpkins

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The Celestial Sphere

- Construct to help understand diurnal and seasonal motions.
- Stars are “glued” to a transparent crystal/plastic sphere.
- The Earth’s N&S poles project out to the celestial sphere’s N&S poles.
- The Earth’s equator projects out to the celestial sphere’s equator.

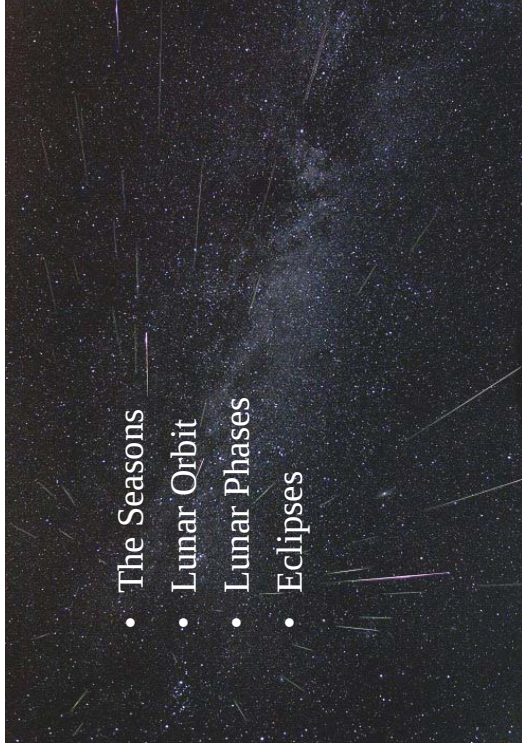


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Outline

- The Seasons
- Lunar Orbit
- Lunar Phases
- Eclipses

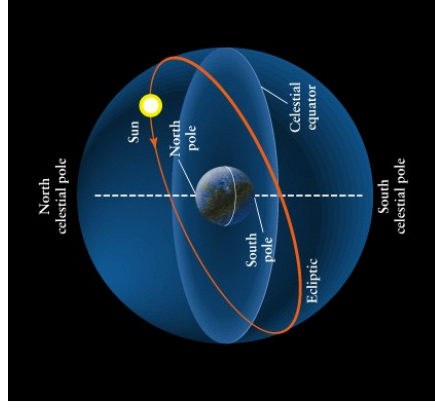


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The Ecliptic on the Celestial Sphere

- The ecliptic is the great circle that the Sun appears to travel during the Earth’s yearly journey.
- Note, the ecliptic and the celestial equator are not the same circles
- The Earth’s axis is tilted to the ecliptic plane by 23.5°



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The Gregorian Calendar

- Actually, the revolution period is 365.2422... days long
- A regular calendar year is 365 days long
- Accounting for difference
 - Leap years: 1 extra day every 4 years = 365.25 days
 - No leap years every 100 years = 365.24 days
 - Add leap year every 400 years = 365.2425 days



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What Causes the Seasons?

The Earth is closer to the Sun in the summer!

No!

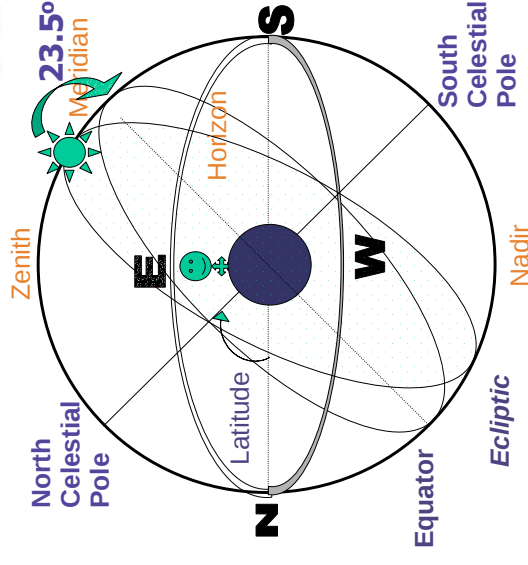
- While the Earth's orbit is not perfectly circular, it is actually closest to the Sun in *January*
- Also, summer in Northern Hemisphere is winter in Southern and vice versa



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Building A Celestial Sphere



- NCP is up from horizon at an angle equal to your latitude
- Equator is 90° from NCP
- Ecliptic is 23.5° tilted from equator

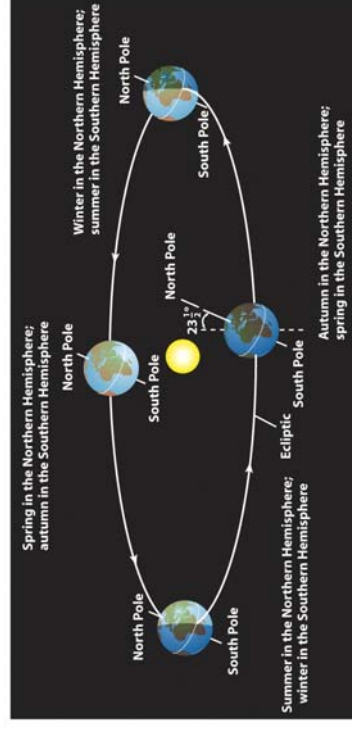
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What Causes the Seasons?

So what does cause the seasons?

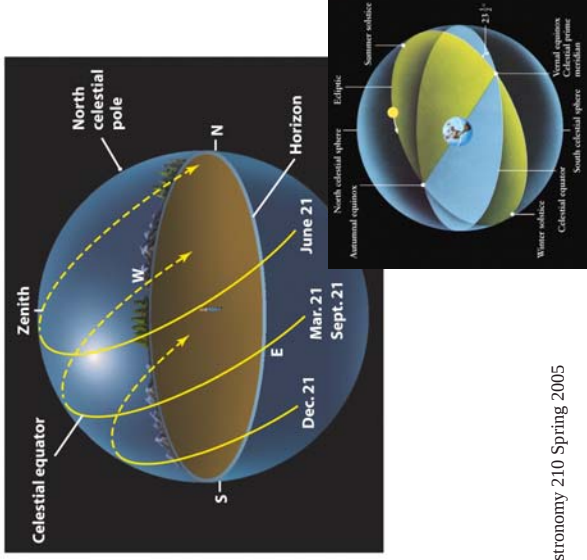
- It's the effects of the Earth's spin axis tilt.
- Note, the direction of the tilt doesn't change over the year



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Sun's Daily Paths

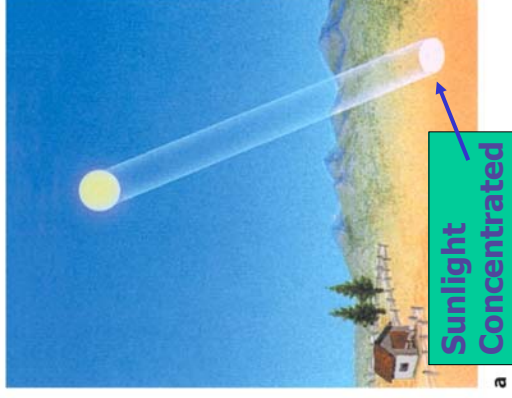
- In the summer, the Sun is north of the celestial equator
 -
 -
 -
- In the winter, it is south of the celestial equator
 - Short days
 - Low in the sky
 - Indirect sunlight



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Summer vs. Winter

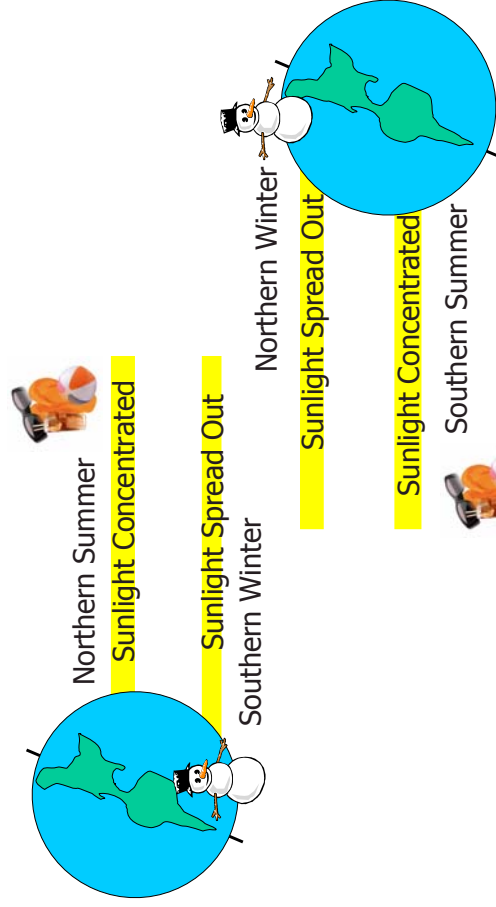


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Seasons Around the World

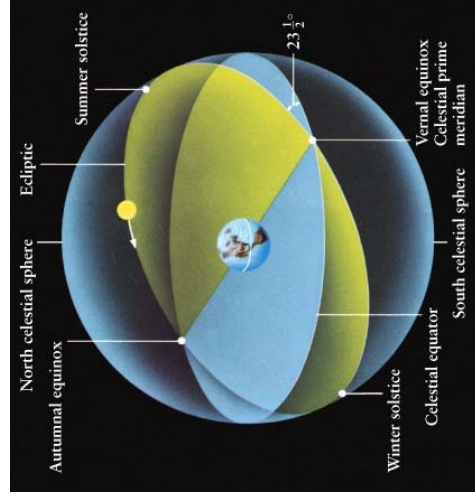


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Solstices and Equinoxes

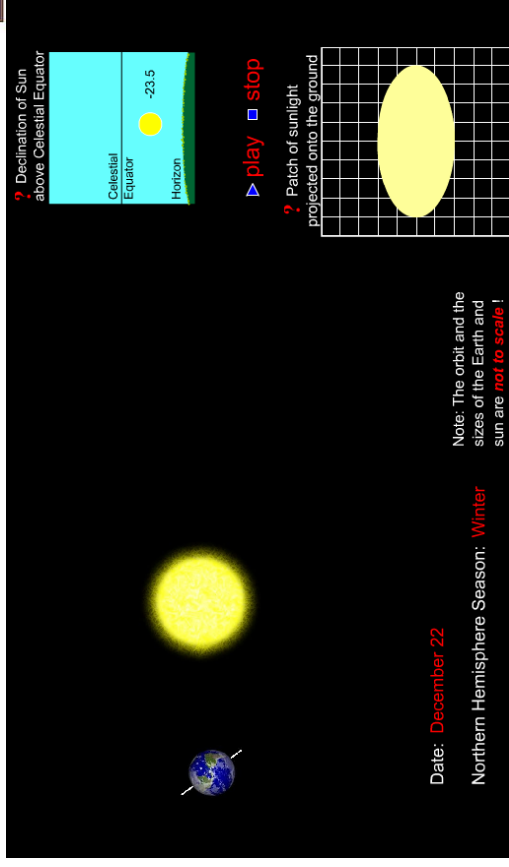
- **Solstices**
 - Most northern and southern points on the ecliptic
 - Longest and shortest amounts of daylight
- **Equinoxes**
 - When the ecliptic crosses the celestial equator
 - Daytime and nighttime equal



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Seasons Animation



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Solstices and Equinoxes



- Winter Solstice – December 21
 - 9 hours of daylight, 15 hours of night
- Spring (“Vernal”) Equinox – March 21
 - 12 hours of daylight, 12 hours of night
- Summer Solstice – June 21
 - 15 hours of daylight, 9 hours of night
- Fall (“Autumnal”) Equinox – Sept 21
 - 12 hours of daylight, 12 hours of night

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The Tropics



- Over the year, the Sun varies from 23.5° north to 23.5° south of the celestial equator
 - If you live between 23.5° N and 23.5° S latitude, the Sun can reach the zenith – directly overhead
 - Sun never gets directly overhead in Urbana, 40° N
- Between 23.5° N and 23.5° S latitude is called the tropics
 - 23.5° N – Tropic of Cancer
 - 23.5° S – Tropic of Capricorn

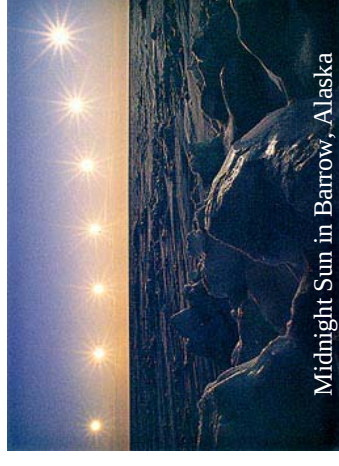
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The Arctic and Antarctic



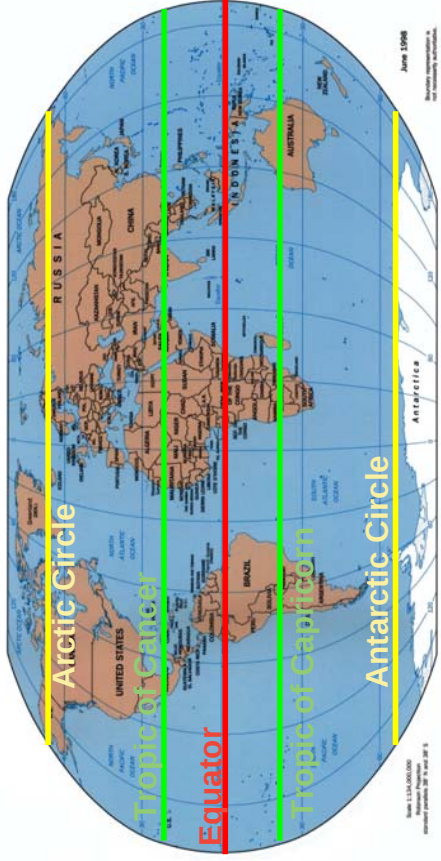
- Above 66.5° N and below 66.5° S latitudes (90 – 23.5 = 66.5), the Sun can be *circumpolar*!
- North of 66.5° N
 - The Arctic
- South of 66.5° S
 - The Antarctic



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Tropics and Arctics



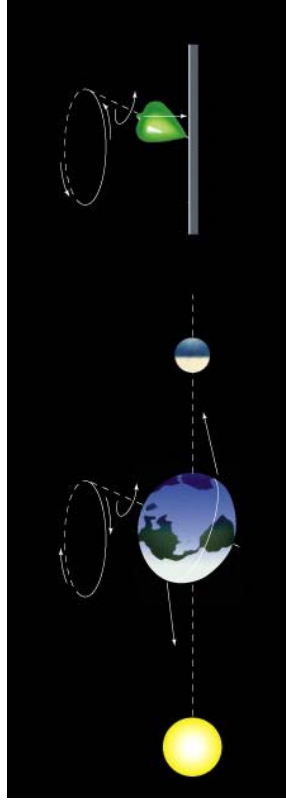
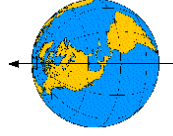
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Precession



- As the Earth spins it also wobbles slowly, like a top
 - This wobble takes 26,000 years
 - Geek-speak: Called **precession**



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Question



We've argued today that the two effects that cause the seasons are:

- The duration of the day
- The tilt of the Earth's axis wrt the plane of the Ecliptic: indirect vs. direct sunlight

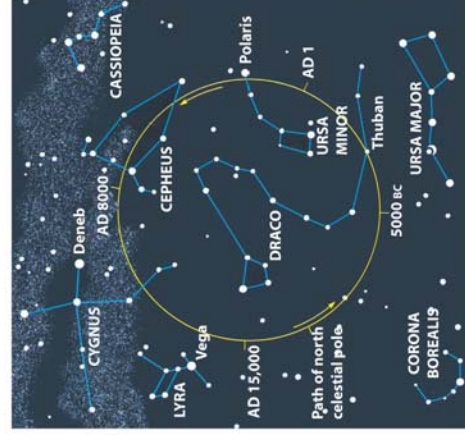
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What Does This Mean?



- Polaris won't always be the North Star!
- In the time of the Egyptian pharaohs, it was Thuban
- In about 13,000 AD it will be Vega (sort of)



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“Thinking Cap” Question

June 21st is the summer solstice and December 21st is the winter solstice.

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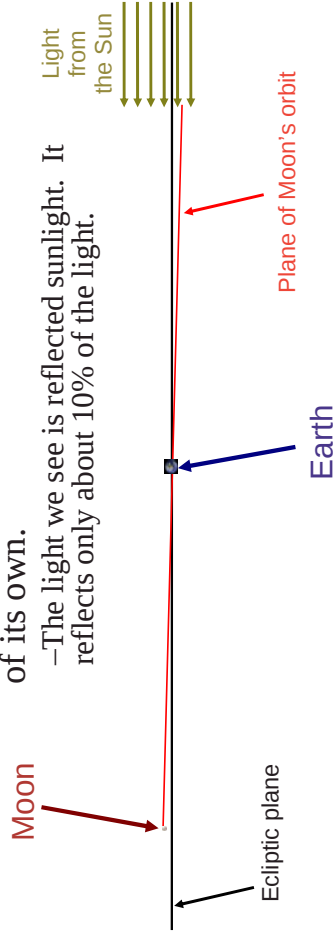


The Lunar Orbit

- The Moon is Earth's nearest neighbour in space
 - About 30 Earth diameters away
- Orbits the Earth once in a little under a month
 - Like the Earth orbits the Sun, the Moon orbits the Earth counter-clockwise

- The Moon does not give off any light of its own.

–The light we see is reflected sunlight. It reflects only about 10% of the light.



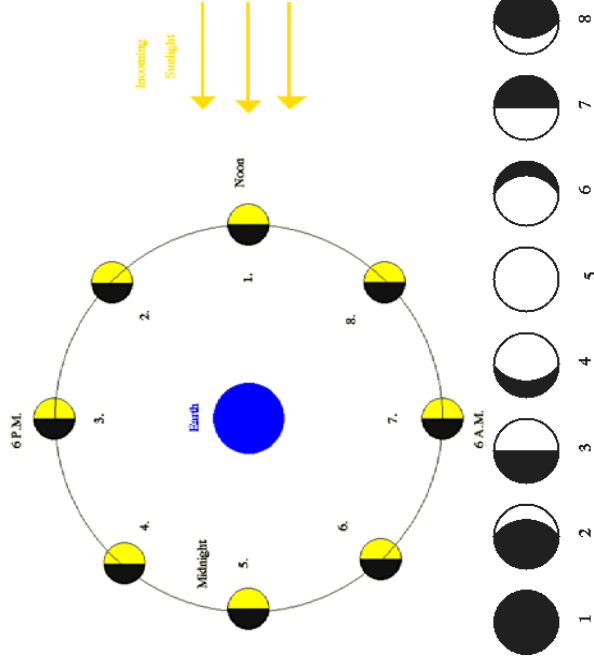
Phases of the Moon



- Over the orbit, the Moon's appearance changes radically
- The apparent **Phases** of the Moon depend on how much of the sun-lit side of the Moon we can see.
- This is caused by the relative positions of the Earth, Moon, and Sun.
- **Not** caused by the shadow of the Earth

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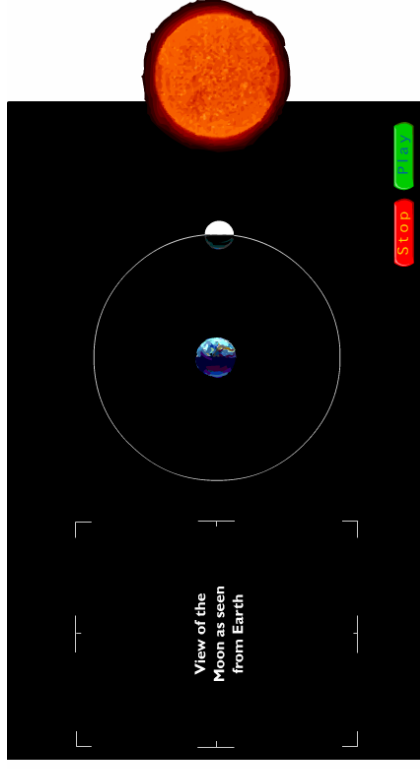


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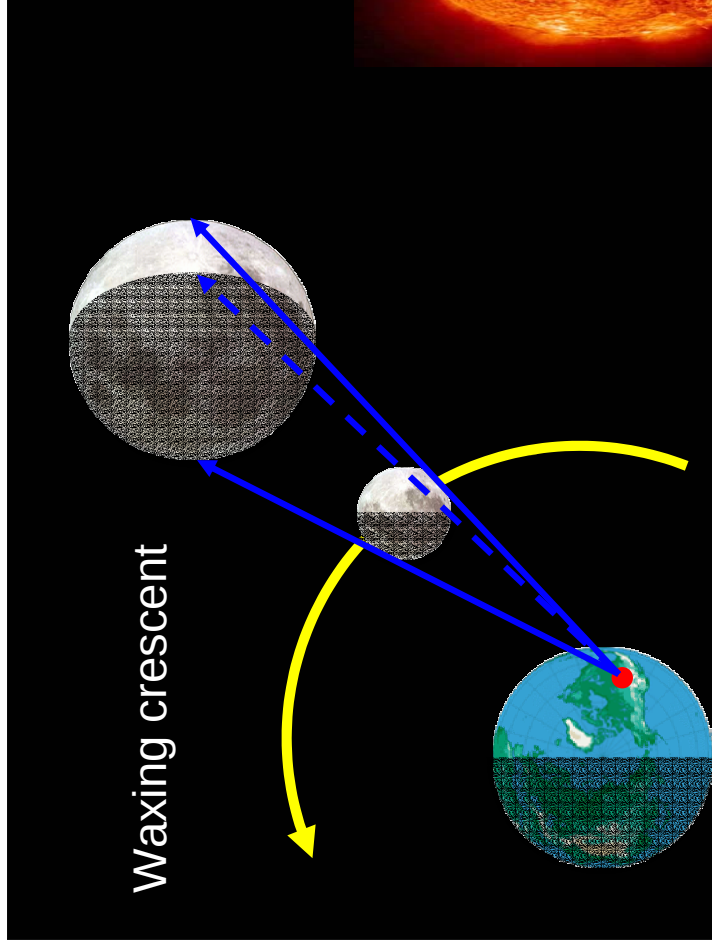
The Cycle of Phases

As the Moon orbits the Earth, we see it go through a cycle of phases



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At Home Phases Demo



- Hold a softball (or equivalent) toward the sun (or a lightbulb)
- Spin around, and watch the ball experience phases like the Moon!

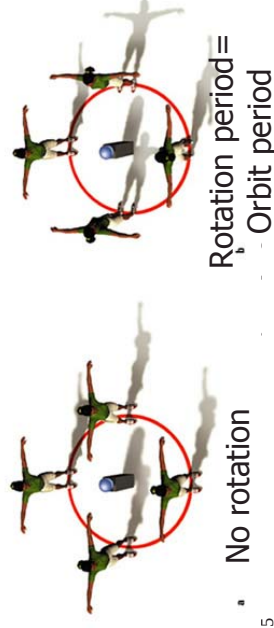
<http://www.astro.uiuc.edu/projects/data/MoonPhases/index.html>

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The Face of the Moon

- Did you notice that we only see one face of the Moon?
- Does this mean the moon doesn't rotate?
- *No*, the Moon rotates so that the same face is always pointed at the Earth
- A lunar day equals a lunar orbit!



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Dark Side of the Moon?



Is there really a dark side of the Moon?

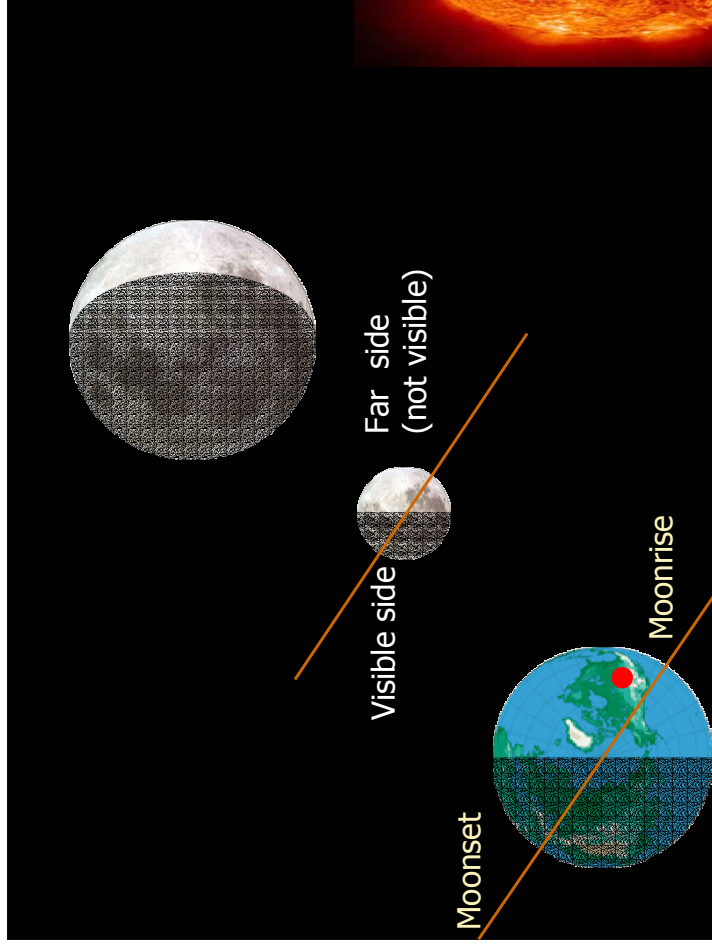
NO! It is better called the Far Side of the Moon.

There is a side we don't see, but during the New Moon phase, it is well lit.

Basically the lunar day is nearly a month long.

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A "Moonth"

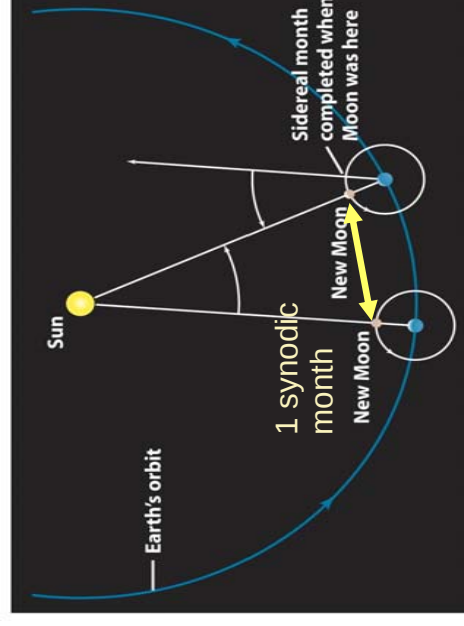


- The month is based on the time it takes the Moon to cycle through its phases
 - 29.5 days – called *synodic period*
- Moon makes one full orbit of the Earth in 27.3 days
 - Called its *sidereal period*
- Because of the Earth's orbit about the Sun, the Moon travels more than a full orbit each synodic period
 - $360 \text{ degrees} / 27.3 \text{ days} = 13.2 \text{ degrees/day}$
 - Earth rotates about 15 degrees/hour
 - So Moon rises $13.2/15 \text{ hours} = 53 \text{ minutes}$ later each day

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Synodic vs. Sidereal Period



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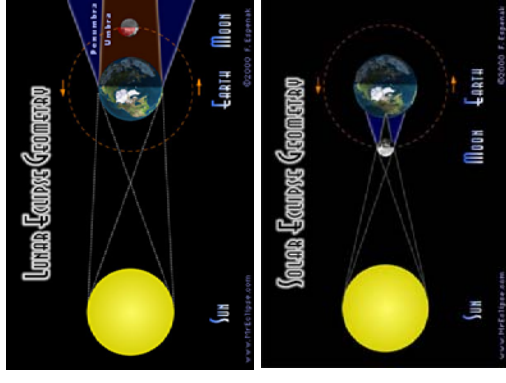
Synodic vs. Sidereal Period



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Basic of Eclipses



- Lunar Eclipse
 - When the Moon passes into the Earth's shadow
 - Sun – Earth – Moon
full moon
- Solar Eclipse
 - When the Earth crosses the Moon's shadow
 - Sun – Moon – Earth
new moon
- Why don't eclipses happen *every* full and new moon?

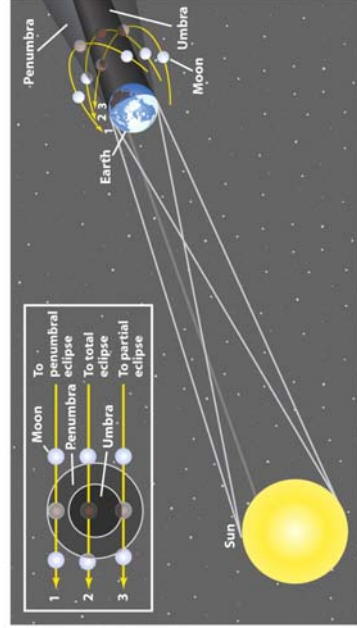
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Lunar Eclipses



- Three types
 - **Total** - The Moon goes completely through the Earth's umbra
 - **Partial** – The Moon only goes partly through the umbra
 - **Penumbral** – The Moon only passes into the penumbra



Umbra? Penumbra?

Latin for "complete shadow" and "partial shadow"

Total Lunar Eclipse– Time Lapse



- Occurs when the Moon passes through Earth's umbra completely.



- Occur roughly twice a year, and last for about an hour or two.
- Can be seen by anyone experiencing night during the lunar eclipse.

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<http://www.mreclipse.com/LEphoto/TLE2000/T00sequence1w.JPG>

Red Moon

- During a total lunar eclipse, the Moon turns a blood-red/burnt orange color.

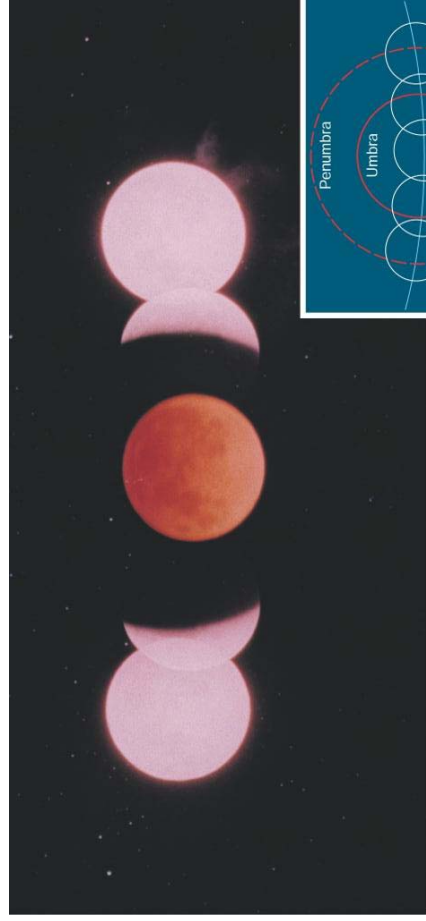


- Red color caused by sunlight diffused through the Earth's atmosphere
- Atmosphere scatters blue light away, so Moon is dimly illuminated in red
- The next total eclipse visible in Champaign-Urbana will be in 2007.

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Eclipsed

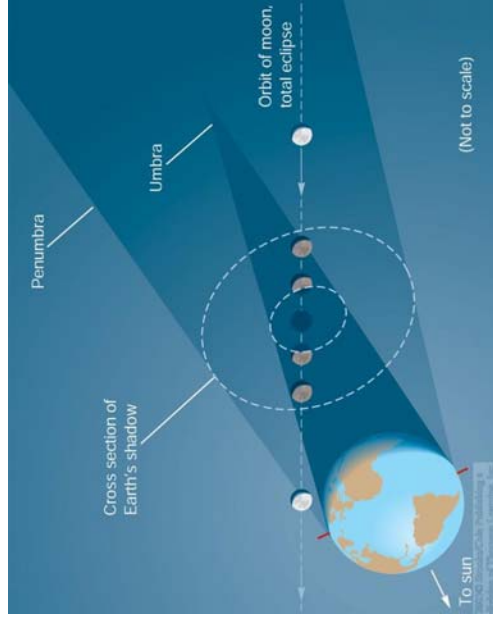


Color depends on Earth's Atmosphere

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Total Lunar Eclipse

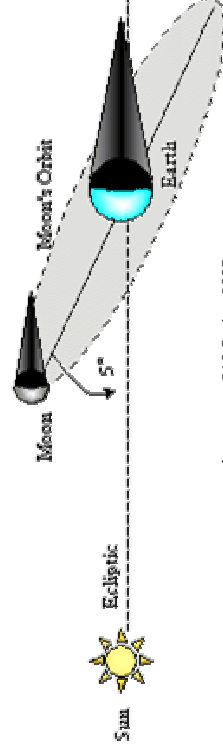


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The Moon's Orbit is Tilted!

- The Moon's orbit is tilted to the ecliptic
- Just like the Earth's rotation axis is tilted to the ecliptic
- The Moon must be near the ecliptic for an eclipse to occur



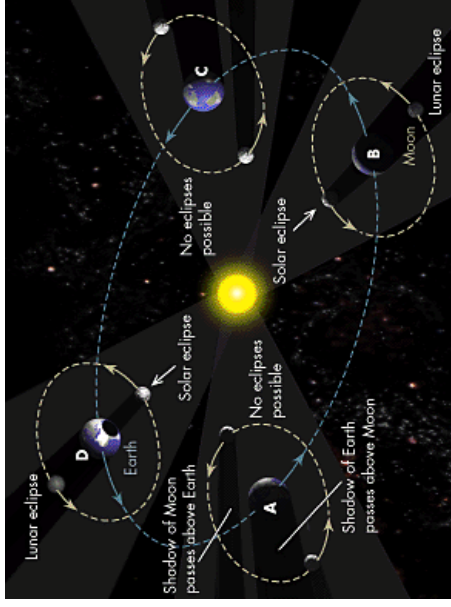
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Eclipse Seasons



Nodes are the two points in each orbit at which the Moon crosses the Earth's orbital plane. For lunar or solar eclipses to occur the nodes must be aligned with the Earth and the Sun. Hence, eclipses can occur only twice per year and these epochs are called eclipse seasons.



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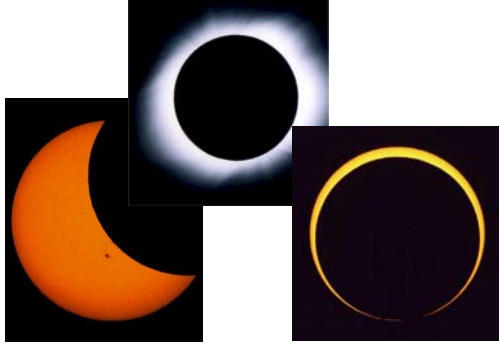
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<http://www.uctw.edu/~mhamy/moon.html>

Solar Eclipses



- Earth passes into the Moon's shadow
- Only occur at the new moon
- Three types
 - **Partial** – when the moon only partially blocks the sun
 - **Total** – when the moon completely blocks the sun
 - **Annular** – when the moon is too small to completely block the sun



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