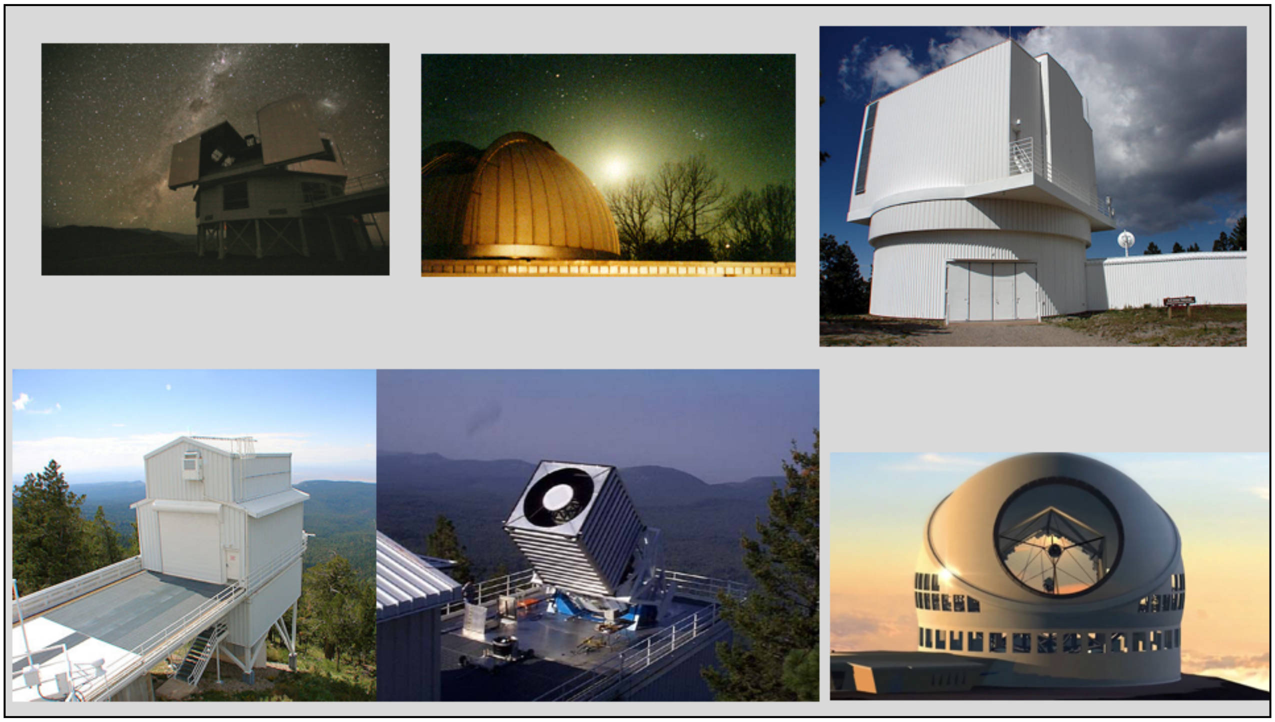
Midterm exam review!

Why do telescopes have round domes?

Not all do, but many do. And almost every old observatory has a round dome.

- I asked a few astronomers.. None of us know for sure, but we have some ideas.
  - Efficiency: it's the surface with the smallest area that will let the telescope move 180 degrees in altitude and 360 degrees in direction
  - Materials cost: back in the late 1800s and early 1900s, steel would have been used-and it would have been expensive. The least amount you need, the better.
  - Aerodynamics? Maybe now, but back then builders probably weren't thinking about it very much.
  - Today, we have a number of observatories with non-dome structures

It may sound surprising, but I have learned a lot teaching this class. You ask great questions, and much of the time, they're things I've just taken for granted and never wondered why, myself!



Magellan/Clay 6.5m telescope (upper left). Three College Observatory dome, 0.8m (middle top). Apache Point Observatory 3.5m ARC telescope dome (upper right).

Lower left/middle: SDSS telescope, at APO. Lower right- illustration of the proposed TMT (thirty-meter telescope).

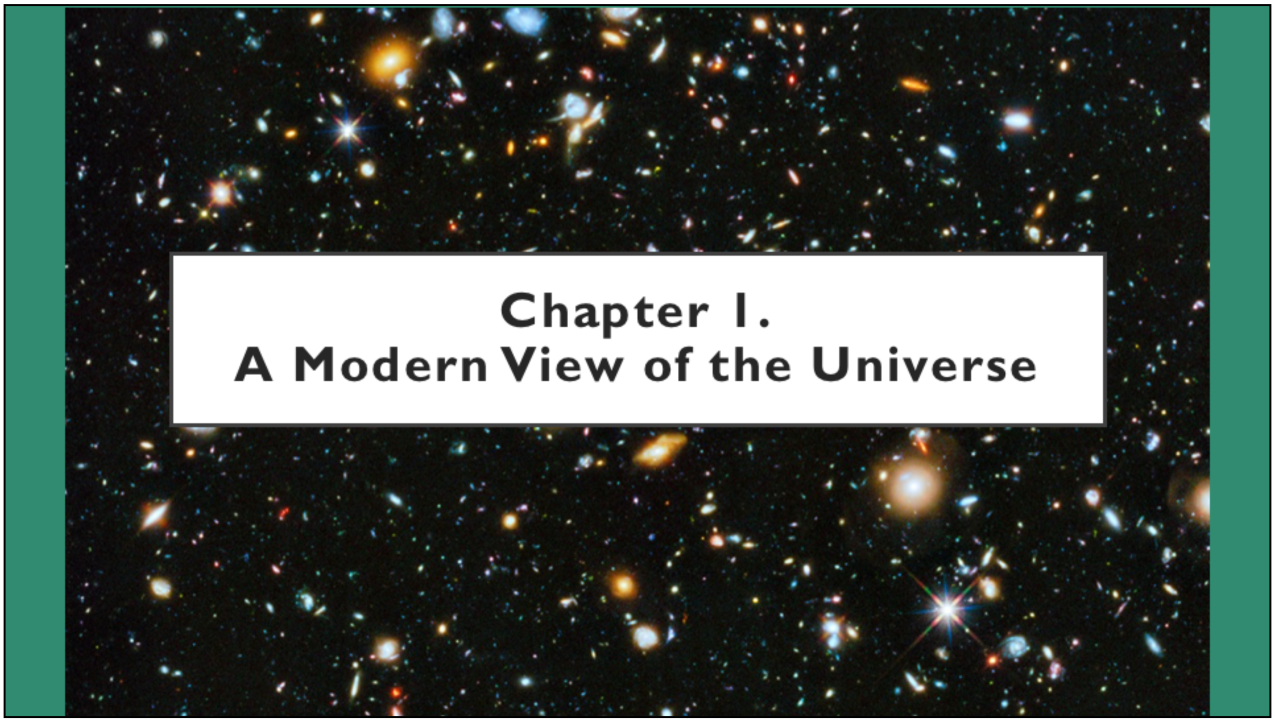
Today's class

- Slides will not be posted online until after class (I'm sorry!)
- Have Clickers out and ready
- There will be bingo, easter egg hunts, clicker multiple choice questions, fill-in-the-blanks, and free response
  - For prizes!! 10 grand prizes, other random candy prizes
- Clicker questions today will be full credit for answering
- If you forgot your clicker, write down your answers as we go and give me that sheet with your name at the end of class. Or, type on phone/laptop and email them to me ASAP at the end of class. Once the slides are online, (2pm) I won't accept responses.

At the end of class, tell me how many times…

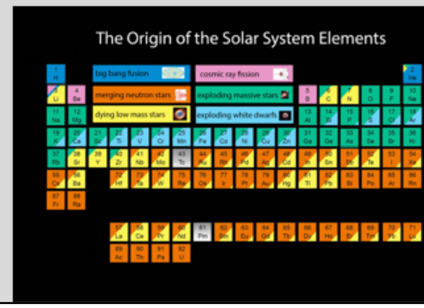
- You saw equations in today's slides
  - Repeated on same slide counts
- You saw the word "rotation," "rotate(s)," or "rotating" in today's slides
- How many pictures of planets were in today's slides
  - Earth included, actual images not cartoons or filled in circles

- You felt relieved because I went over something again you feel confident you know!


Chapter 1.
A Modern View of the Universe

Definitions and perspective

- Basic definitions: planet, star, cluster of stars, galaxy, cluster of galaxies
- Size scales: from small to large,
  - Planet, star, cluster of stars, galaxy, cluster of galaxies
- Light-years, a unit of distance
- The farther away something is, the farther back in time you're looking
- The history of the universe:
  - The big bang, H only in the beginning
  - Stars process elements, we are made of star stuff



Clicker free response:
If extra-terrestrials on a distant planet could observe Earth in great detail, where would they be to see the dinosaurs?

Info needed:
Triassic period: ~240 million years ago
Jurassic period: ~200 million years ago
Cretaceous period: ~145 million years ago

"Brilliant disguise, Agent X."

Clicker free response:
If extra-terrestrials on a distant planet could observe Earth in great detail, where would they be to see the dinosaurs?

Info needed:
Triassic period: ~240 million years ago
Jurassic period: ~200 million years ago
Cretaceous period: ~145 million years ago

They would be 145 million to 240 million light years away.

"Brilliant disguise, Agent X."

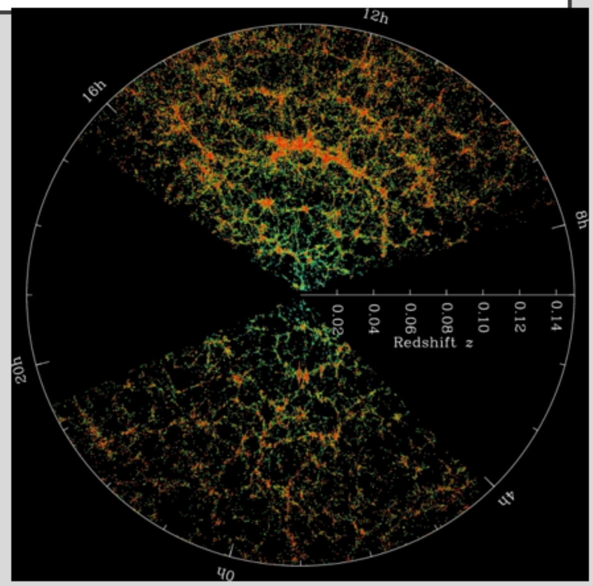
The Cosmic Calendar

- The entire age of the Universe – 1 year
  - The Milky Way formation – February
  - The Solar System formation – August 13
  - Large creatures appeared on Earth – December 13
  - Dinosaurs vanished – December 30
  - Early humans – December 31, 9:00 p.m.
  - Egyptian pyramids built – 13 seconds ago
  - Your birth – 0.1 second ago

Most of what we know is SO RECENT cosmically speaking

Cosmic Motions

- As we sit/stand here…
  - Earth is rotating
  - We're orbiting the Sun
  - The Sun is orbiting the Milky Way
  - The Milky Way is moving in the Local Group
  - The Local Group is part of a Supercluster of galaxies
  - Superclusters of galaxies are entrained in an expanding Universe



https://www.e-education.psu.edu/astro801/content/l10_p6.html

Practical, social, technological shifts

- Astronomy…
  - has practical applications:
    - navigation
    - calendar systems
  - Has been a driver of revolutions in:
    - social change and thought: our idea of our place in the Universe in part depends on what we think the universe is
    - our perception of the planet (round!)
    - in the Universe (it doesn't revolve around the Earth)
- Astronomy, astrophysics, and space research have led to huge advances in technology
  - Newton's laws laid foundation for the industrial revolution
  - space travel
  - computation

Copernicus proposed a heliocentric view in 1543. Galileo, Brahe, and Kepler made the observations that proved it; Galileo was put under house arrest by the church for heresy in 1633. Galileo was forgiven officially py Pope John Paul II in 1992!

Unit conversions review

- Example: Convert 5 light-hours to Alicia-heights

5 light-hours = X Alicia-heights

1 Alicia-height = 64 inches = 1.6 m

$$X = 5 \text{ light-hours} * \frac{1 \text{ Alicia-height}}{1.6 \text{ m}} * \frac{9.46\text{x}10^{15} \text{ m}}{1 \text{ light-year}} * \frac{1 \text{ light-year}}{365.25 \text{ light-days}} * \frac{1 \text{ light-day}}{24 \text{ light-hours}} = 3.37\text{x}10^{12} \text{ Alicia-heights}$$

Astronomical Distances

1 AU $\approx 1.496 \times 10^8$ km $= 1.496 \times 10^{11}$ m

1 light-year $\approx 9.46 \times 10^{12}$ km $= 9.46 \times 10^{15}$ m

1 parsec (pc) $\approx 3.09 \times 10^{13}$ km ≈ 3.26 light-years

1 kiloparsec (kpc) $= 1000$ pc $\approx 3.26 \times 10^3$ light-years

1 megaparsec (Mpc) $= 10^6$ pc $\approx 3.26 \times 10^6$ light-years

You did this on your homework for chapter 1, there have still been a few questions about it so let's recap

Does this check out? Does the answer make sense? Light travels very very quickly, and Alicia is pretty short, so .. In 5 light hours, yes- light should travel a whole lot of Alicia heights in distance

Remember the ruler I brought in? 30cm in 1 nanosecond. 10^-9! So to get to even 1 light second, you need one billllioonnnn of those rulers! 10^9 of them!

Unit conversions review

- Another way to think about it…
- Start by converting 5 light-hours into m
- Use 1 Alicia-height = 1.6m to convert that to Alicia-heights
- Make up your own ridiculous units to practice! For example: How many refrigerators could you set lengthwise from here to Andromeda? Determine whether your answer makes sense.

Astronomical Distances

1 AU $\approx 1.496 \times 10^8$ km $= 1.496 \times 10^{11}$ m

1 light-year $\approx 9.46 \times 10^{12}$ km $= 9.46 \times 10^{15}$ m

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1 megaparsec (Mpc) $= 10^6$ pc $\approx 3.26 \times 10^6$ light-years

Work in pairs or by yourself…

How many refrigerators could you put end to end between here and Andromeda?

- Andromeda is 2.537 million light years away
- The average refrigerator is 66” tall
- Im is 39.37”

Astronomical Distances

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You can use google calculator or open your phone’s calculator and turn it sideways to get the scientific calculator

Multiple ways to approach the problem

In problems where you're comparing two different quantities with different units, you could start by converting one into the same units as the other (first part of method 1 on the right), or convert them both into the same (new) units and directly compare them (the second part of method 1, or all of method 2 on the right).

1. What I did: convert the distance to Andromeda into inches, then divide by the height of the refrigerator in inches
2. Convert the distance to Andromeda into meters, convert the height of the refrigerator into meters, and then divide the distance by the refrigerator size to see how many times a fridge would fit in that distance

If you find yourself unsure of where to start, write down the first quantity you know (the distance to Andromeda in light years). Think about what might be a more useful unit than light years, check the constants bank, and see if you can cancel out the light years and convert it into something like meters or inches. You can do this with just the units and no numbers first, remembering that division cancels out a unit.

Answer: 1.43×10^{22} refrigerators

First, I converted light years into inches, because the fridge size was in inches.

$$2.537 \times 10^{6}\ \text{ly} * \frac{9.46 \times 10^{15}\ \text{m}}{1\ \text{ly}} * \frac{39.37''}{1\ \text{m}} = 9.45 \times 10^{23}\ ''$$

Then, I divided the distance by the fridge height to get the number of fridges.

$$9.45 \times 10^{23}'' * \frac{1\ \text{fridge}}{66''} = 1.4310^{22}\ \text{fridges}$$

How many is that?

14.3 sextillion

or

14,300 quintillion

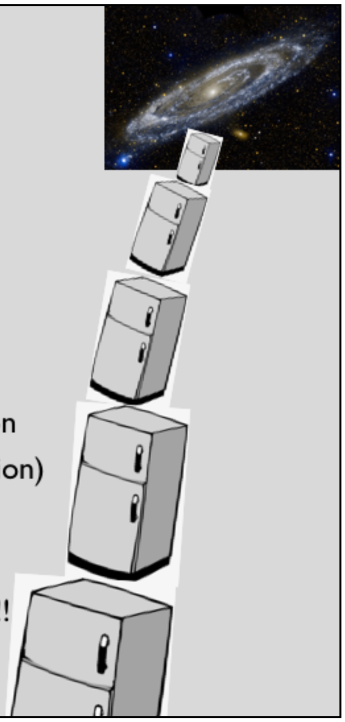
or

14,300,000 quadrillion

(14.3 million quadrillion)

or

14.3 trillion trillions !!



http://www.astronomy.com/news/magazine/2018/02/adromeda-is-the-same-size-as-the-milky-way

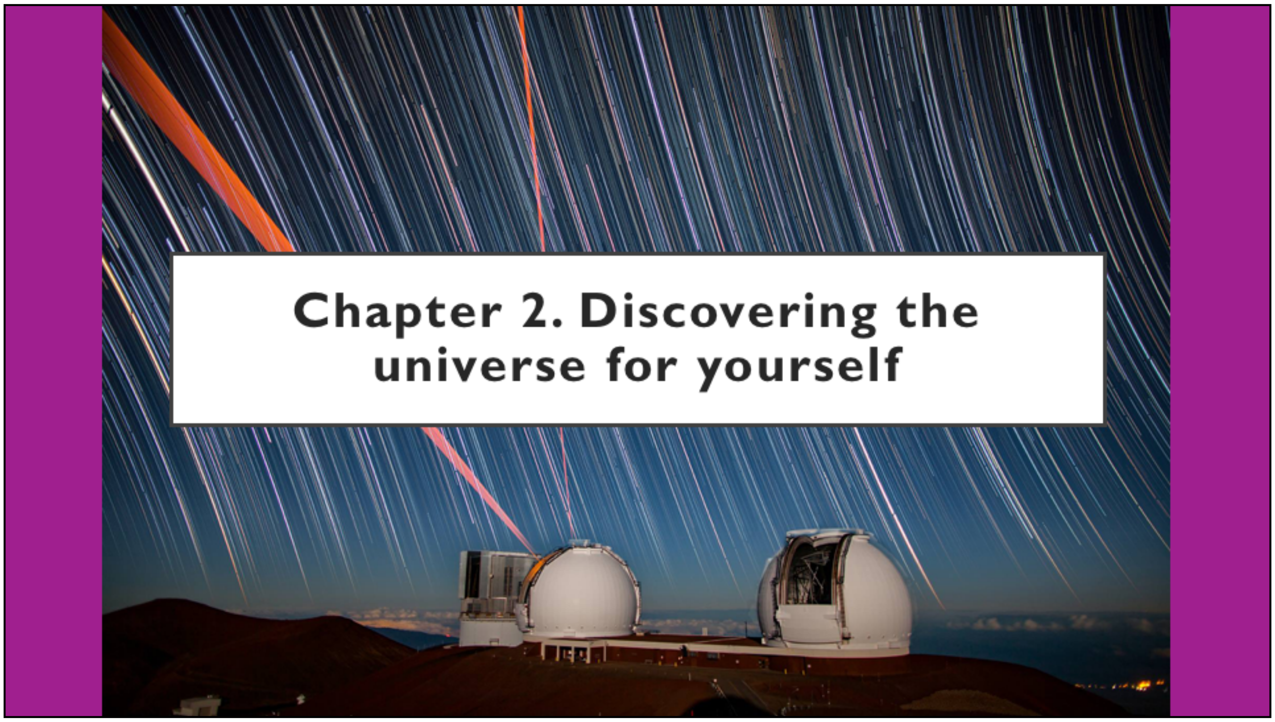
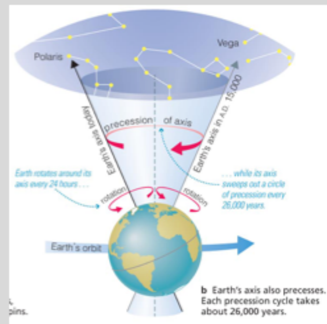


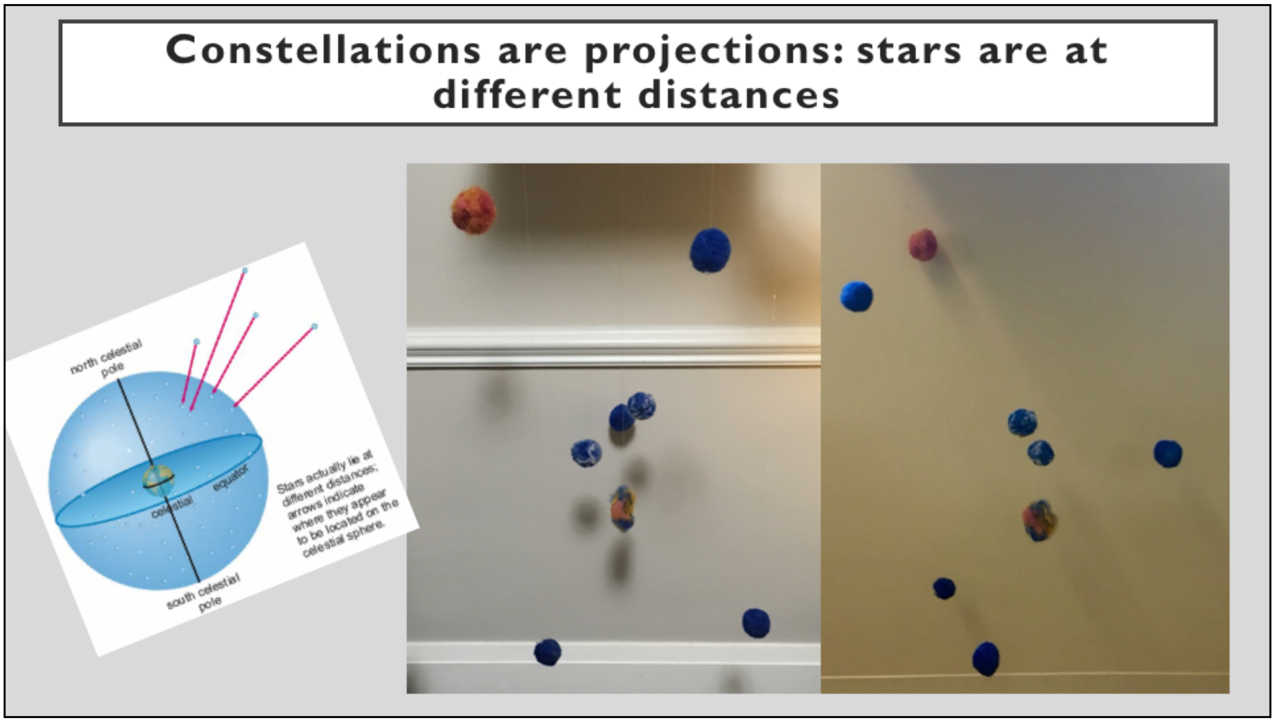
Photo credit: Dr. Joe Llama, Lowell Observatory

Photo is of star trails over Keck Observatory. Yes, those are laser beams coming out of the telescope dome!

All about rotation, tilt, and the celestial sphere

- Earth's rotation and orbit
- Tilt of Earth's rotation axis (23.5°) as the reason for the seasons
  - Earth's rotation axis precesses: Polaris will not always be our North Star
  - Solstices and equinoxes
- Constellations
- Asterisms
- Definitions
  - Locally: horizon, altitude, direction, zenith, meridian
  - Celestially: North Celestial Pole, South Celestial Pole, Ecliptic
- The path of the Sun and stars in the sky depends on our latitude

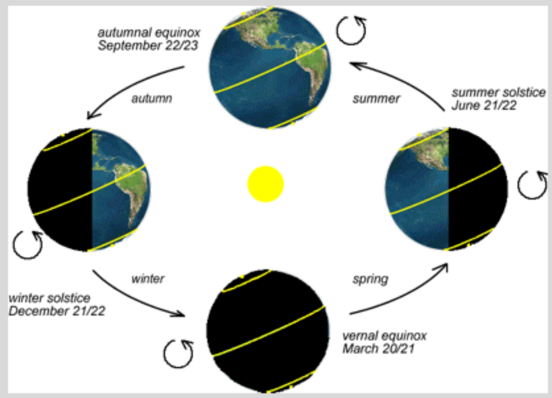




I made a Thing for class. For Science!

Seasons!

- Common misconception:
  - Distance of Earth from Sun causes seasons



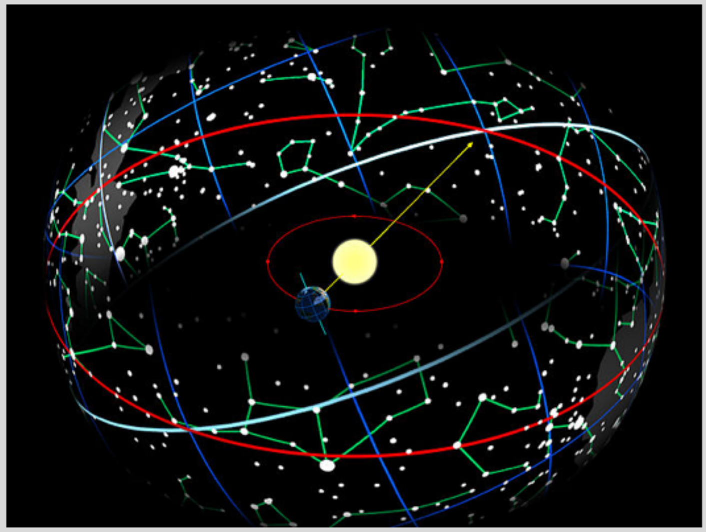
Not an advertisement, just where I found this graphic!

https://www.teepublic.com/t-shirts/axial-tilt-is-the-reason-for-the-season-sweater

http://astronomy.nmsu.edu/geas/lectures/lecture06/slide05B.html

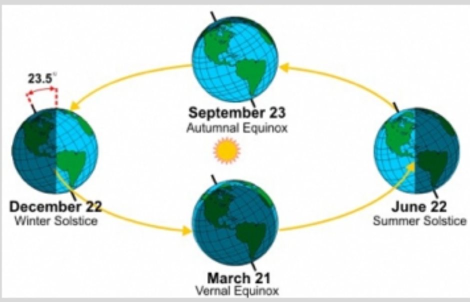
The Celestial Sphere

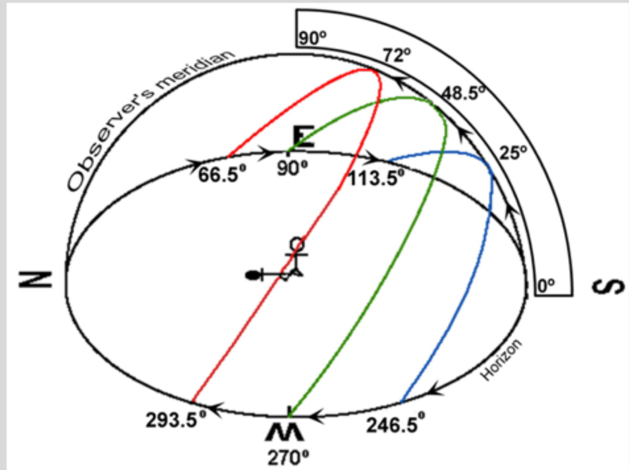
- From Earth's surface to the sky:
  - Equator → Celestial Equator
  - North Pole → North Celestial Pole
  - South Pole → South Celestial Pole
  - Ecliptic: path of Sun in the sky



The Sun's motion

- Where is this observer?





The analemma

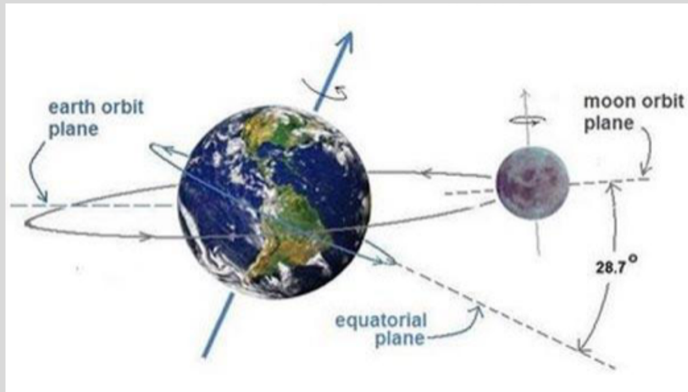
- The path taken in the sky by the Sun over the course of a year
- Each dot is the Sun on a different day of the year
- The shape and angle of the analemma depend on your latitude

’analemma’ was the word for a sundial

https://dept.astro.lsa.umich.edu/resources/ugactivities/Labs/analemma/index.html

All about angular size, phases, and eclipses

- Angular size
- Lunar phases
- Eclipses
  - Lunar
  - Solar (total, partial, annular)



What does the angular size of an object in the sky depend on?

A. How far away it is
B. How hot it is
C. If it's a star or a planet
D. How big it is
E. Both A and D

What does the angular size of an object in the sky depend on?

A. How far away it is
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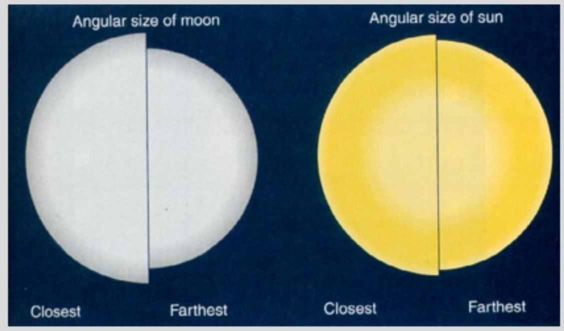
Angular size

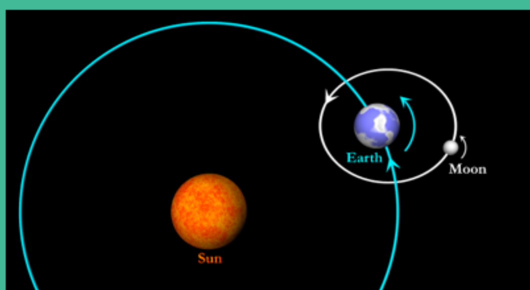
- The angular size of an object depends on
  - An object's physical size
  - The distance to the object
- Example: both the Sun and the Moon are roughly 0.5 degrees in angular size!
  - The Sun is about 400x bigger than the Moon, but..
  - The Moon is 400x closer to us than the Sun



What causes the phases of the moon?

A. Where Earth's shadow falls on the Moon as it orbits
B. The relative positions of the Earth, Moon, and Sun
C. It's B
D. The answer is B

What causes the phases of the moon?



A. ~~Whe[illegible]rth's [illegible]low falls on t[illegible]n as it orbit[illegible]~~
B. The relative positions of the Earth, Moon, and Sun
C. It's B
D. The answer is B

I really, really, want you to know this.

Lunar phases

This is a figure showing what we see from Earth depending on where in the lunar cycle we are

Does the Moon rotate?

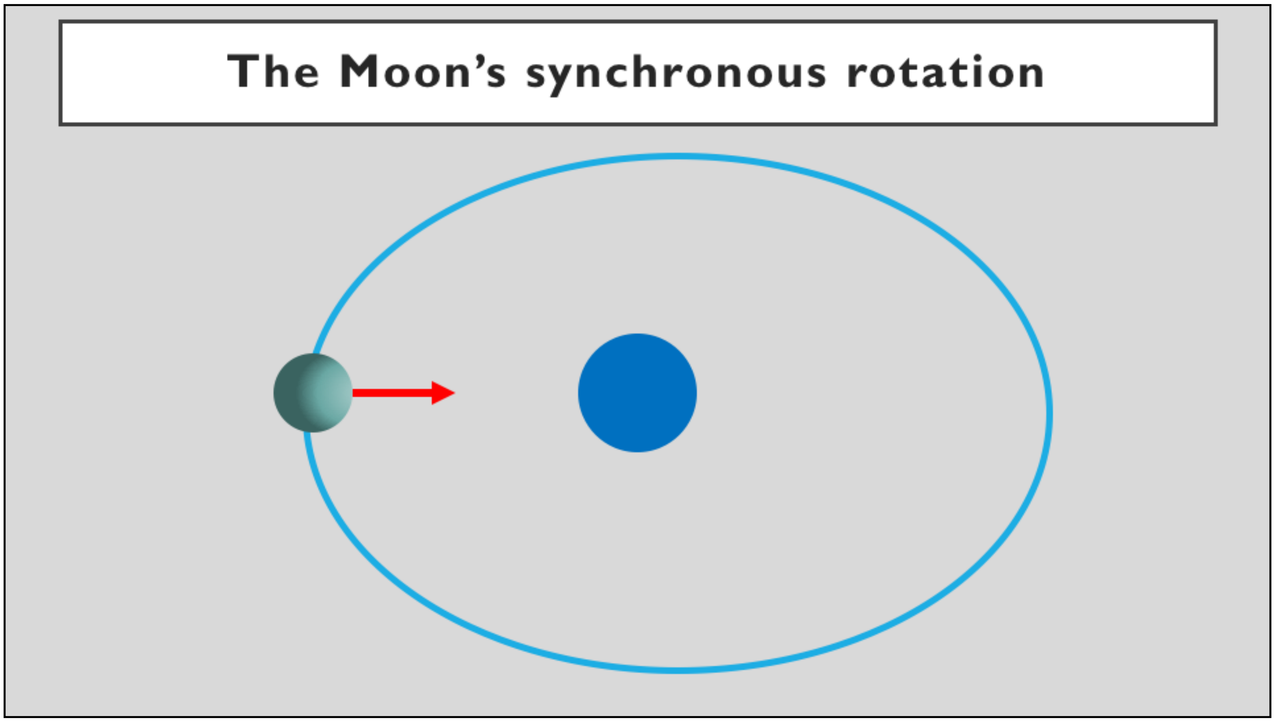
A. Yes

B. No

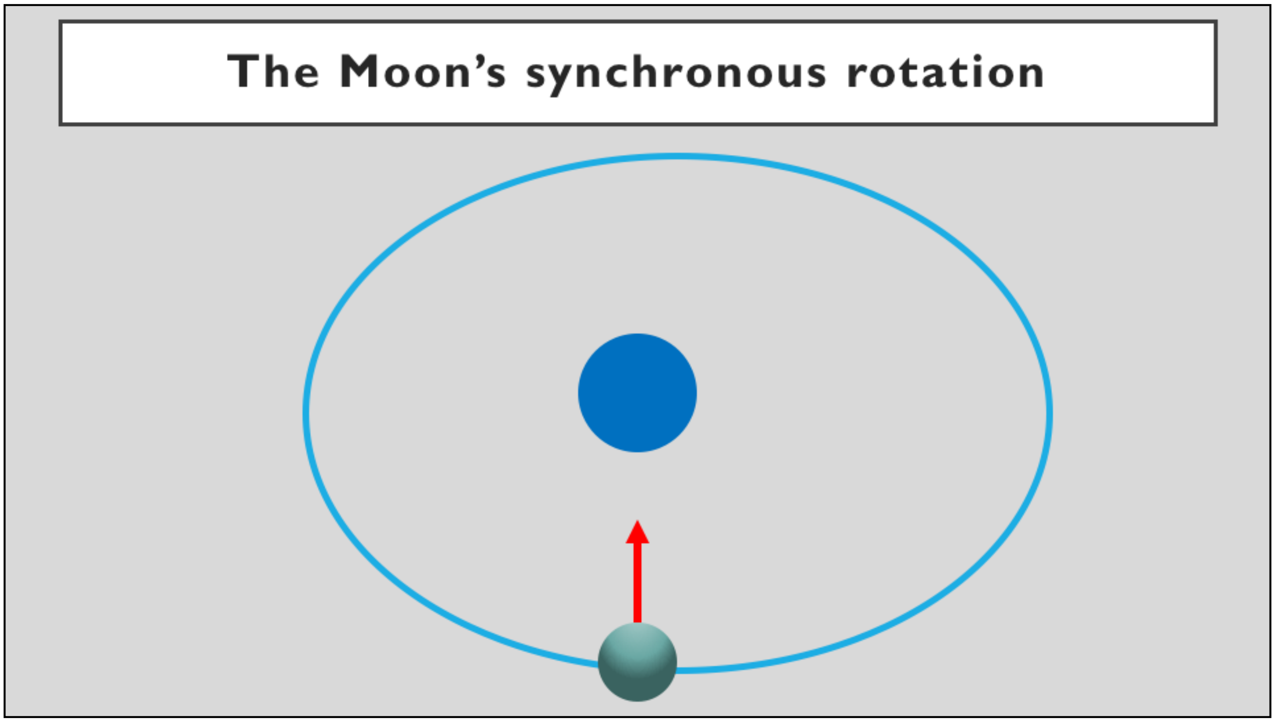
Does the Moon rotate?

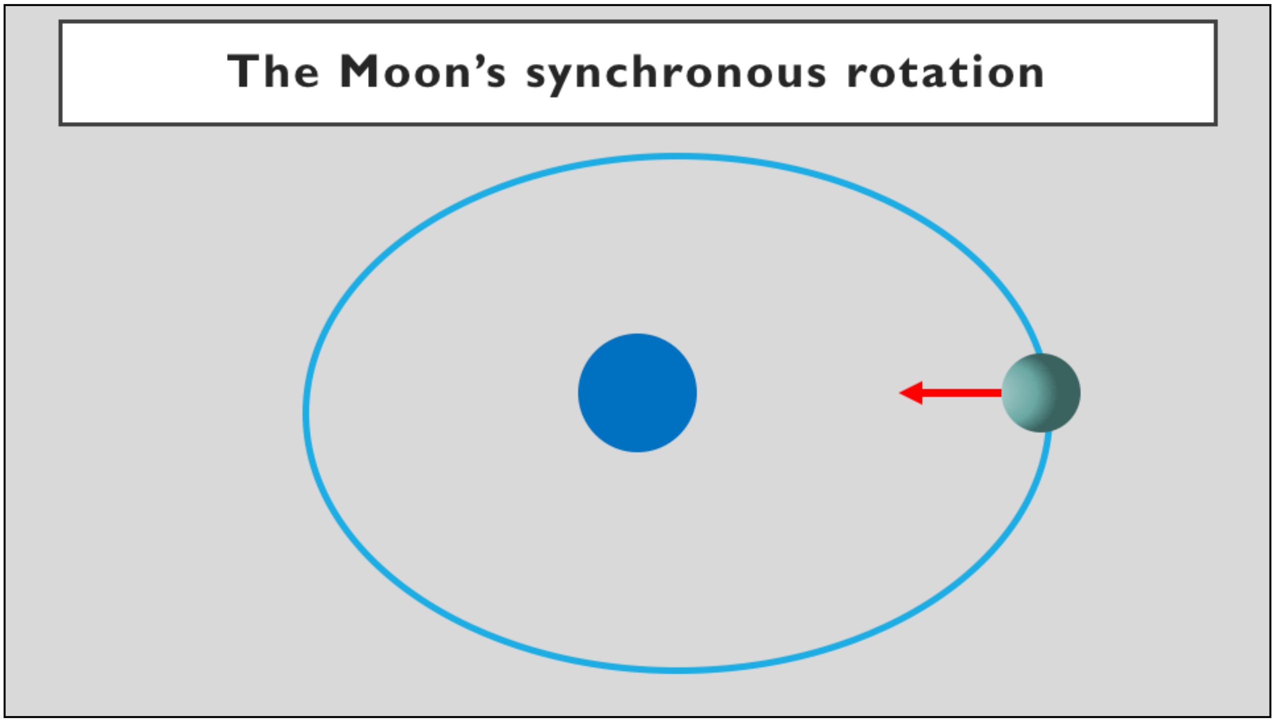
A. Yes

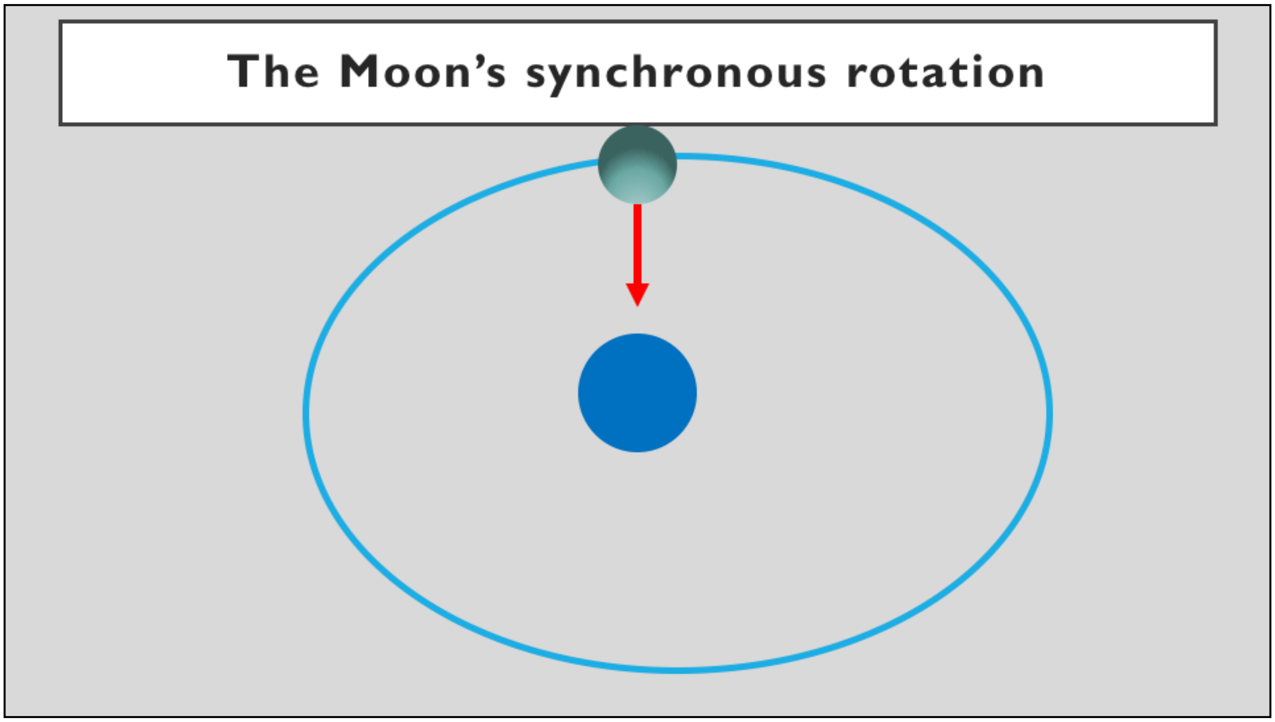
B. No



Let's look at one of the Moon's orbital periods.. Take what we know, which is that we always see one part of the moon

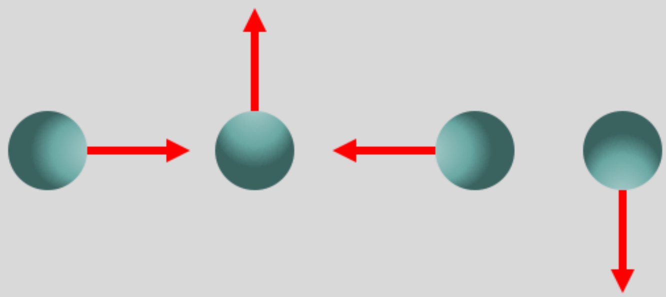

The Moon’s synchronous rotation


The Moon's synchronous rotation


The Moon's synchronous rotation

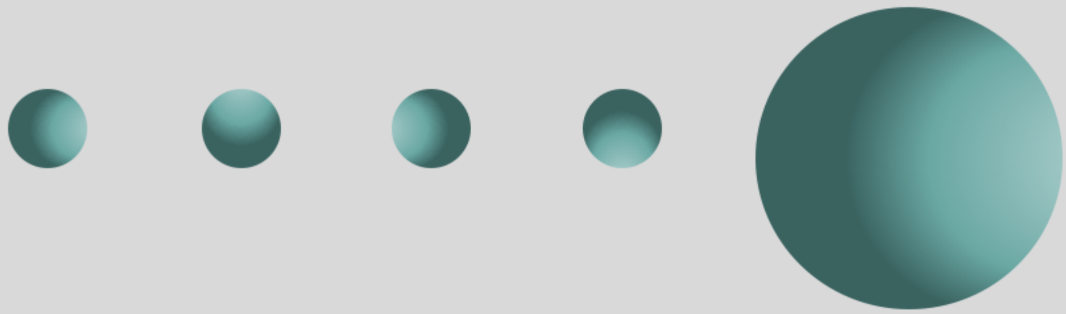
The Moon's synchronous rotation

- Let's isolate just the Moon, and see what it's doing



The Moon's synchronous rotation

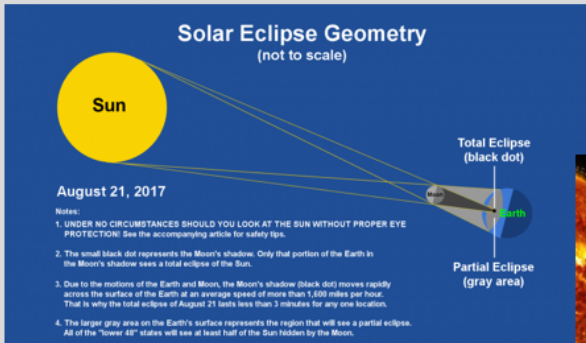
- Let's isolate just the Moon, and see what it's doing
- Completes one rotation in the time it orbits once!

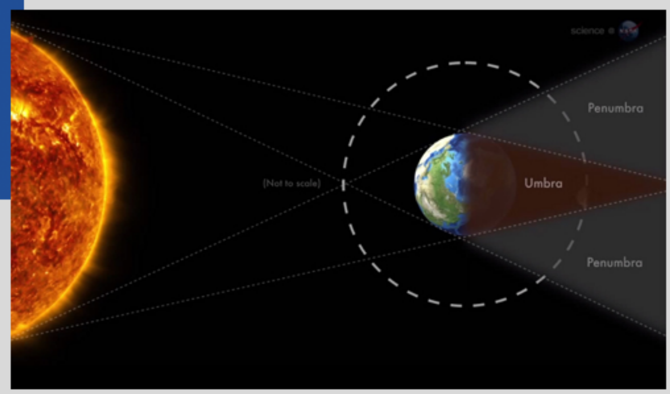


~29 day rotation period, ~29 day orbital period

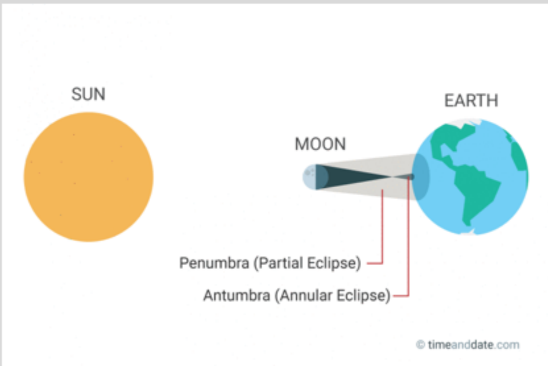
Origin of the word 'month' ('mon' instead of 'moon'th)

Eclipses

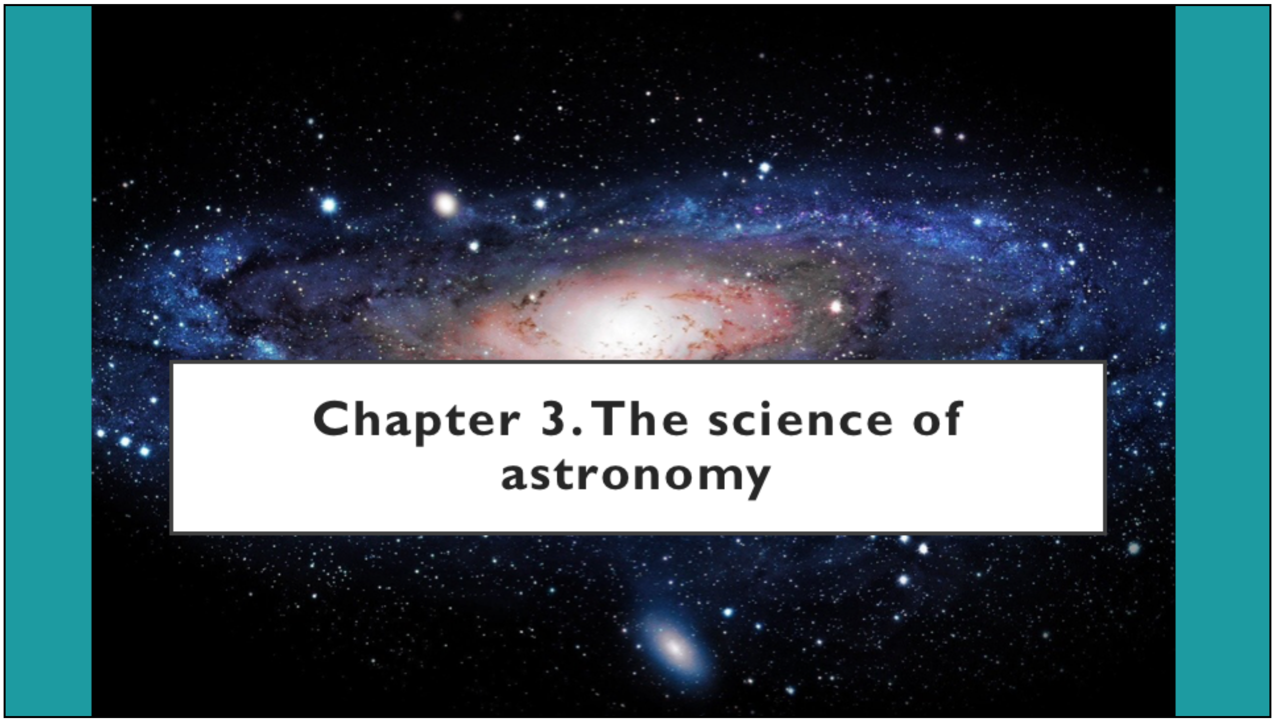

Solar Eclipse Geometry
(not to scale)
Sun
Total Eclipse
(black dot)
Moon
Earth
Partial Eclipse
(gray area)
August 21, 2017
Notes:
1. UNDER NO CIRCUMSTANCES SHOULD YOU LOOK AT THE SUN WITHOUT PROPER EYE PROTECTION! See the accompanying article for safety tips.
2. The small black dot represents the Moon's shadow. Only that portion of the Earth in the Moon's shadow sees a total eclipse of the Sun.
3. Due to the motions of the Earth and Moon, the Moon's shadow (black dot) moves rapidly across the surface of the Earth at an average speed of more than 1,600 miles per hour. That is why the total eclipse of August 21 lasts less than 3 minutes for any one location.
4. The larger gray area on the Earth's surface represents the region that will see a partial eclipse. All of the "lower 48" states will see at least half of the Sun hidden by the Moon.


Penumbra
Umbra
Penumbra
(Not to scale)

(annular) Solar eclipses



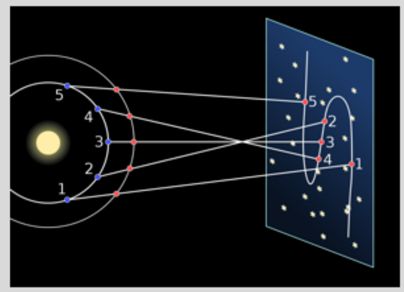
https://www.timeanddate.com/eclipse/annular-solar-eclipse.html



Please fill out and return to Prof. Aarnio at the end of the first class you attend. This is only for Prof. A., will be stored securely, not shared with anyone for any reason, and shredded at the end of the semester for your privacy.

The beginnings, growth, and development of astronomy

- Ancient peoples
  - Time and calendar systems
    - Lunar vs solar
    - Egyptians divided day into 12 and 12 hour blocks, ante- and post-meridiem
  - Architecture aligned to unique times of year
- The Greeks
  - Began applying geometry
  - Eratosthenes: estimated circumference of the Earth
  - Ptolemy, Ptolemaic view: Geocentric, epicycles to explain retrograde motion
    - Lasted 1500 years!

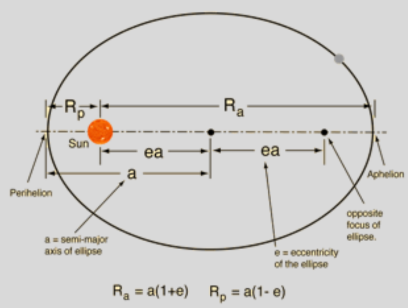


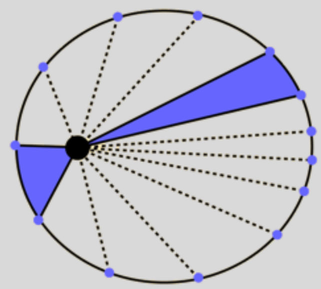
The personalities…

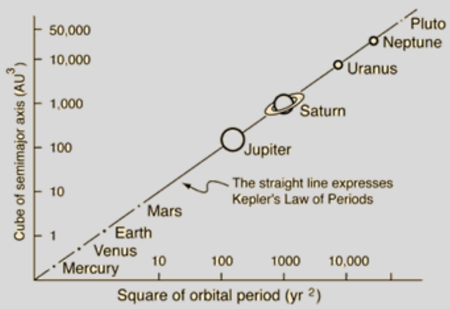
- Copernicus, and revolution:
  - Heliocentric!
  - …but still perfect circular orbits like Aristotle said, and yeah we need epicycles here too
  - Got the order of the inner solar system planets correct
- Tycho Brahe: the dude with the brass nose who measured things very precisely with a huge protractor. Or maybe his sister did a lot of it and didn't get any credit for helping
- Kepler: analyzed Brahe's data, suggested **elliptical** orbits best explain observations

Kepler's Laws

1. Planets move on elliptical orbits
2. The planet's radius-vector sweeps out the same areas in equal times
3. The squares of the periods of the planets are proportional to the cubes of their semi-major axes



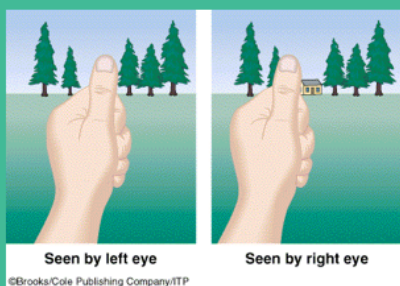




http://hyperphysics.phy-astr.gsu.edu/hbase/kepler.html

What is stellar parallax?

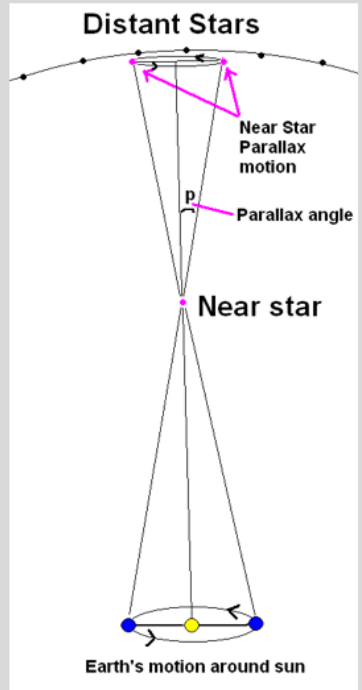
Hint…



A. It's when Mars looks like it's moving backwards in the night sky
B. The apparent shift in a star's position against background (farther away) stars when seen from different places in Earth's orbit
C. Probably B because it's the longest option
D. It's the way light moves in parallel beams toward us

What is stellar parallax?

B. The apparent shift in a star's position against background (farther away) stars when seen from different places in Earth's orbit



Putting geocentrism to rest: Galileo tests Aristotelian thought

Aristotle said:

- If Earth is moving, things falling on the Earth would be left behind as the Earth moves
- The heavens are perfect- ellipses aren't perfect, so orbits and motions **must** be circular
- And, no one had detected stellar parallax yet: if Earth orbits the Sun, this must be happening.

Galileo said:

- (before Newton): objects in motion will stay in motion unless acted against. So, if objects are moving **with** the Earth, they should continue to do so unless something acts against their motion
- Tycho saw a supernova, that's not perfectly symmetric. Neither are sunspots!
- I don't see stellar parallax.. But I see way more stars with this telescope thing than we thought, I bet the faint ones are really far away!

Point, counterpoint.

What else did Galileo see with his telescope that supported heliocentrism and went against Aristotelian views??

A. Moons around Jupiter
B. The curvature of the Earth
C. Phases on Venus
D. Craters on the Moon
E. A, C, and D

What else did Galileo see with his telescope that supported heliocentrism and went against Aristotelian views??

A. Moons around Jupiter
B. The curvature of the Earth
C. Phases on Venus
D. Craters on the Moon
E. A, C, and D

What else did Galileo see with his telescope that supported heliocentrism and went against Aristotelian views??

A. Moons around Jupiter
   - Earth isn't the only body being orbited

B. The curvature of the Earth
   - The Greeks first observed this with ships coming over the horizon, seeing sails first

C. Phases on Venus
   - The phases he observed could only be explained by Venus orbiting the Sun as well

D. Craters on the Moon
   - Another argument against celestial perfection


The nature of science and the scientific method

Terminology

- Data – properties, generally measured, of processes or phenomena
- Observation – data collection without interfering with the phenomenon
- Hypothesis – a question: an initial scientific interpretation of processes or phenomena being observed that needs to be tested to verify
- Experiment – a procedure designed to collect data to test the hypothesis; could include manipulating the phenomenon in a controlled way to better understand it
- Model – a simplified version of reality developed to explain observations
- Law – a general rule to which many sets of data conform
- Theory – an in-depth scientific interpretation of a phenomenon, or a whole group of phenomena, that is capable of making correct predictions

While a law sounds better than a theory, it's not necessarily. Theories are more robust developments of ideas, while laws can be a single equation that describe a lot of data well.

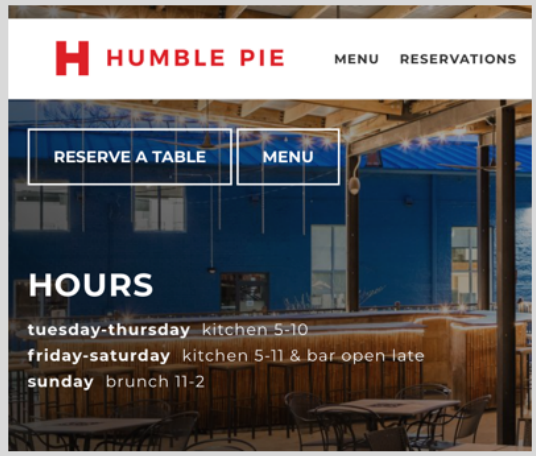
The scientific method

- The scientific method is an approach, a framework for asking and trying to answer questions, for better understanding the Universe
- **The major steps of the scientific method:**
  - Observe and wonder
  - Formulate the hypothesis
  - Observe more, conduct tests, experiment
  - Interpret the data and results
    - Was your hypothesis correct? Good! Keep testing to be sure it always does that, to see how far it applies
    - Results reject hypothesis? Reform, create and test new hypothesis
    - Unclear? Keep observing, testing, and questioning!

The more you know, the more you know you don’t know.

Validity of a Scientific Theory

- It's valid until… it's not!
  - Newton suggested his law of gravitation in the 1660's
    - All possible experiments showed that it was correct until the end of the 19th century. Until…
    - The precession of the perihelion of Mercury was discovered, and until it was realized that
    - Newtonian models predict only half of the light deflection by gravity
  - Einstein's theory of relativity showed we hadn't learned everything yet about gravity's effects!



That's just science. You can come up with an idea that's amazing and works on almost all the data, but not all of it. We've all been to have that heaping helping of humble pie, it's part of the job.

This is not an advertisement (though it is in Raleigh, and ooh- brunch!)

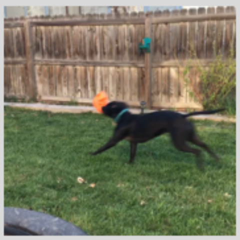
All scientific progress is building on the work of those who came before.

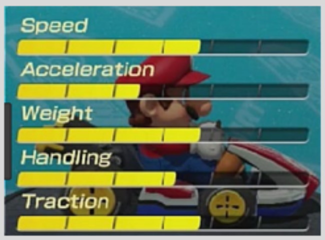
The next two lectures will be about the fundamental forces we use to understand the world around us and the universe

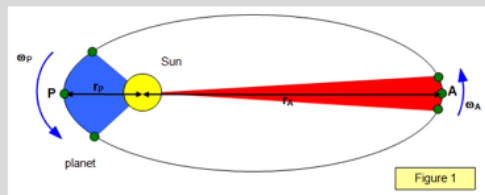
https://apod.nasa.gov/apod/ap151209.html

Describing motion

• Position	• [x, y, z]; m
• Speed	• distance/time; m/s
• Velocity	• [speed in x, speed in y, speed in z]; m/s
• Acceleration	• change in velocity over time; m/s^2
• Momentum	• p=m*v; kg*m/s
• Angular momentum	• ω = m*v*r; $kg*m^2/s$







We talked about my dog running around to start thinking about how to describe something's motion. I used MarioKart as an example for how important momentum is. I talked about both rotational angular momentum as well as orbital angular momentum

What is the difference between speed and velocity?

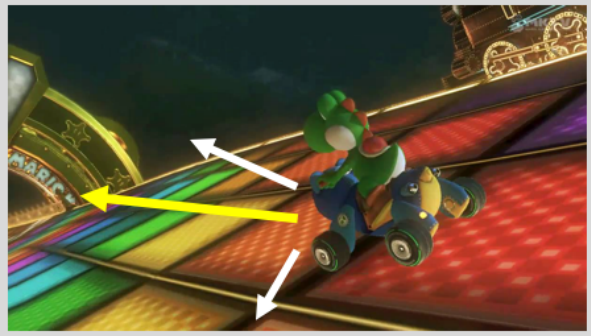
A. They have different units.
B. Velocity includes speed *and* direction.
C. Nothing, they are different words for the same thing.

What is the difference between speed and velocity?

Velocity is a vector

$V = [V_x, V_y, V_z]$

A. They have different units.
B. Velocity includes speed *and* direction.
C. Nothing, they are different words for the same thing.



What is the difference between linear momentum and angular momentum?

A. One is always much bigger than the other
B. Only one depends on mass
C. One is momentum in a straight line and the other is momentum on a curved path
D. They're the same thing

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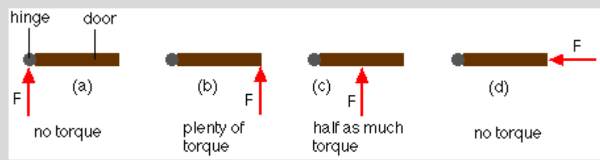
You apply a ____ to change an object's linear momentum, and apply a ____ to change its angular momentum.

A. Torque, force
B. Force, force
C. Force, torque
D. Torque, torque

You apply a ____ to change an object's linear momentum, and apply a ____ to change its angular momentum.

A. Torque, force
B. Force, force
C. Force, torque
D. Torque, torque

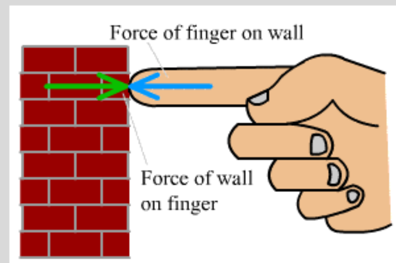
Think of a door rotating on a hinge: *where* you apply the force affects how well it moves the door! This makes a torque a distinct kind of force.



http://physics.bu.edu/~duffy/py105/Torque.html

Newton's Laws of Motion

1. In the absence of a net force, an object in motion or at rest remains in motion or at rest
2. Force = mass * acceleration (F = m * a)
3. For any action (applied force) there is an equal and opposite reaction (force)



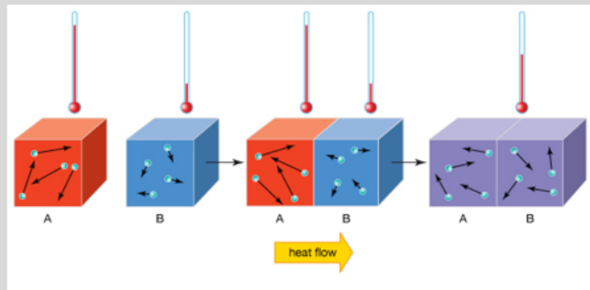
Recall that acceleration is the change in the velocity per unit time- if you regroup the terms in the equation, you get a change in momentum per time; that's what force is

Energy

- Energy is a property that enables something to do work
- When a force acts to move an object a certain distance, it has done work
  - Work = force * distance
- For astronomy, important types of energy:
  - Kinetic
  - Radiative
  - Potential

Kinetic energy

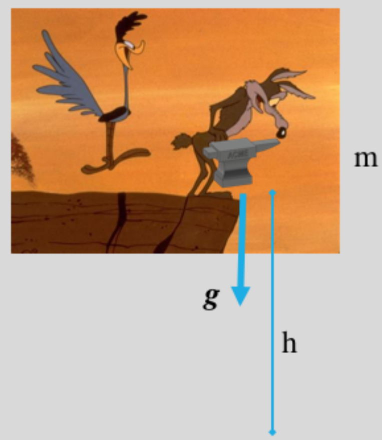
- The energy of a moving object: KE = $\frac{1}{2} mv^2$
  - Units: kg * m^2/s^2 → Joules
- Important form of kinetic energy for us: thermal energy
  - Kinetic energy of atoms or molecules in a substance
- Temperature: measures the *average* kinetic energy
- Temperature tells us which way energy will move when two systems come into contact

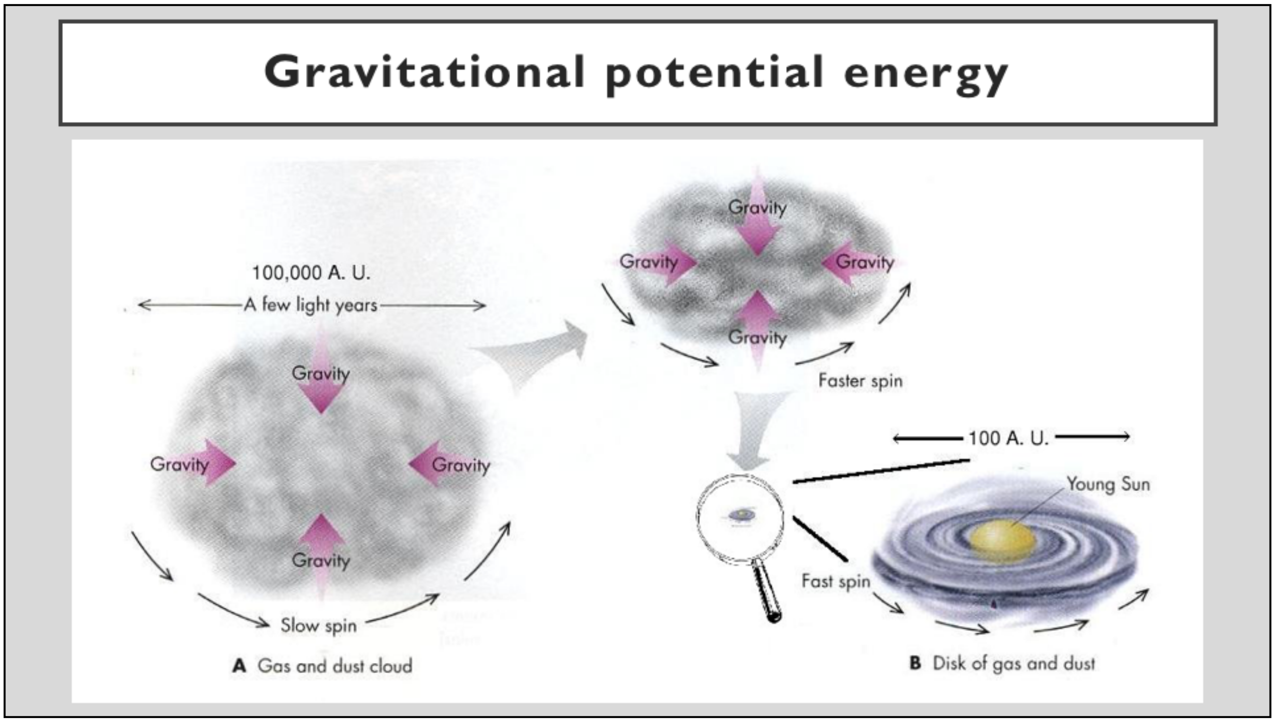


The book gives a good example of a boiling pot of water vs an oven. The oven may be hotter, meaning the particles have higher average kinetic energy, but there are fewer of them than say, in a pot of boiling water.

Potential energy

- Potential energy is the capacity of something to do work
  - Example: if Wile E. Coyote is holding an anvil over a cliff, about to drop it, its potential energy depends on
    - The mass of the anvil
    - The acceleration due to gravity
    - The height of the cliff
      - PE = m*g*h





Gravitational potential energy decreases the smaller the protostellar cloud gets

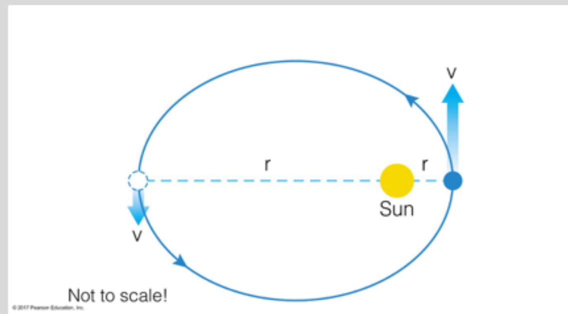
Thermal energy increases because density is increasing; the star forms in the middle, getting heated up from conversion of potential to kinetic energy

Due to conservation of angular momentum, we think material speeds up as it collapses

http://faculty.virginia.edu/skrutskie/ASTR1210/notes/ssrecip.html

Conservation laws in astronomy

- Conservation of momentum
- Conservation of angular momentum
- Conservation of energy



Something we observe here on Earth: conservation of linear momentum; that is to say, momentum acting in a straight path

Remember, in this class I did a demo with billiard balls on a string to show how momentum was transferred from one ball to another, and how momentum of the first ball was equal to momentum of the second ball

Universal law of gravitation

- Newton, not content to stop at laws of motion, calculus, optics, etc… carried on to develop a framework for understanding gravity

1. Every mass attracts every other mass through a force called gravity
2. the strength of the force of gravity is *directly proportional* to the product of those two masses
3. the strength of the force of gravity decreases as the square of the distance between the two masses' centers

$F_g = G*M_1*M_2 / d^2$

The "universal" part is really important: Newton was clear that these laws of motion don't just apply to objects on Earth (sorry, Aristotle…)

Note the big G- this is a universal constant, not to be confused with the little g for acceleration due to gravity on earth

What happens to the gravitational force between two objects if you double one of their masses?

$F_g = G*M_1*M_2 / d^2$

A. F_g quadruples
B. F_g gets weaker
C. The distance between them decreases
D. F_g doubles

What happens to the gravitational force between two objects if you double one of their masses?

$F_g = G*M_1*M_2 / d^2$

If M_1 is doubled…

$F_g = G*(2*M_1)*M_2 / d^2$

$F_g = 2*G*M_1*M_2 / d^2$

A. F_g quadruples
B. F_g gets weaker
C. The distance between them decreases
D. F_g doubles

The force due to gravity is **directly proportional** to the product of the masses.

What happens to the gravitational force between two objects if you quadruple the distance between them?

$F_g = G*M_1*M_2 / d^2$

A. F_g stays the same
B. F_g gets stronger
C. The value of G changes
D. F_g gets 16x weaker

What happens to the gravitational force between two objects if you quadruple the distance between them?

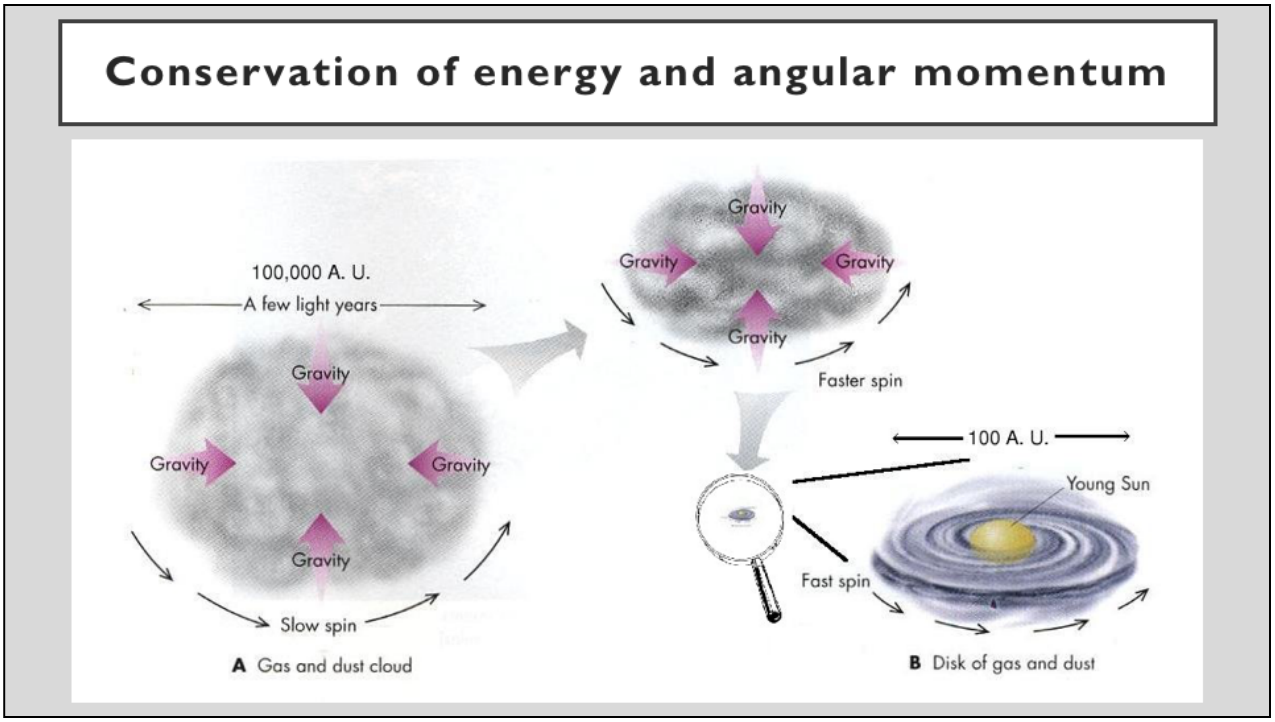
$F_g = G*M_1*M_2 / d^2$

If d is quadrupled…

$F_g = G*M_1*M_2 / (4*d)^2$

$F_g = G*M_1*M_2 / 16*d^2$

A. F_g stays the same
B. F_g gets stronger
C. The value of G changes
D. F_g gets 16x weaker



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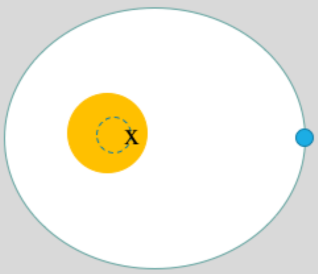
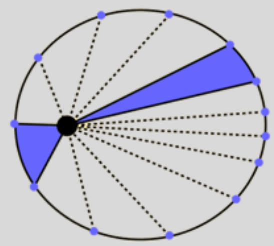
Due to conservation of angular momentum, we think material speeds up as it collapses

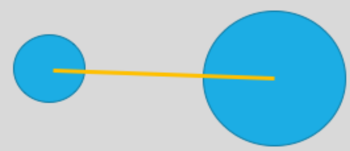
http://faculty.virginia.edu/skrutskie/ASTR1210/notes/ssrecip.html

Kepler's laws and Newton's laws

- Kepler found the how, Newton found the why
  1. Planets travel in elliptical orbits around the Sun
  2. Planets cover equal areas in equal time along their orbits
  3. Planets' orbital periods and semimajor axis radii are related as $p^2 = a^3$
     - Planets experience less force due to gravity farther away from the Sun, and they move more slowly ($F_g \sim 1/d^2$)

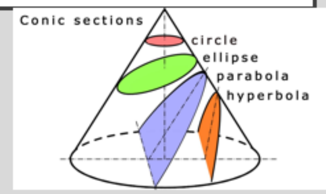


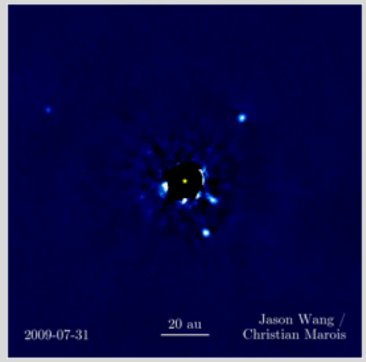




Beyond Kepler's laws

- Newton kept going…
  - Planets aren't the only bodies that travel in elliptical orbits: so do moons and asteroids
- Ellipses aren't the only kinds of orbits
- Knowing orbital parameters, we can now calculate masses of orbiting bodies using the universal law of gravitation

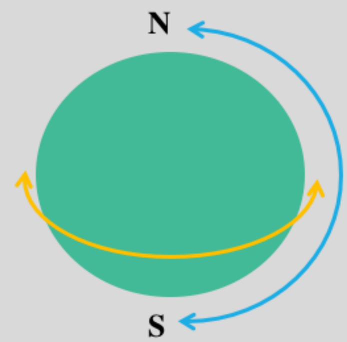




This is the cone Neil deGrasse Tyson was talking about in the video last week

Tidal effects

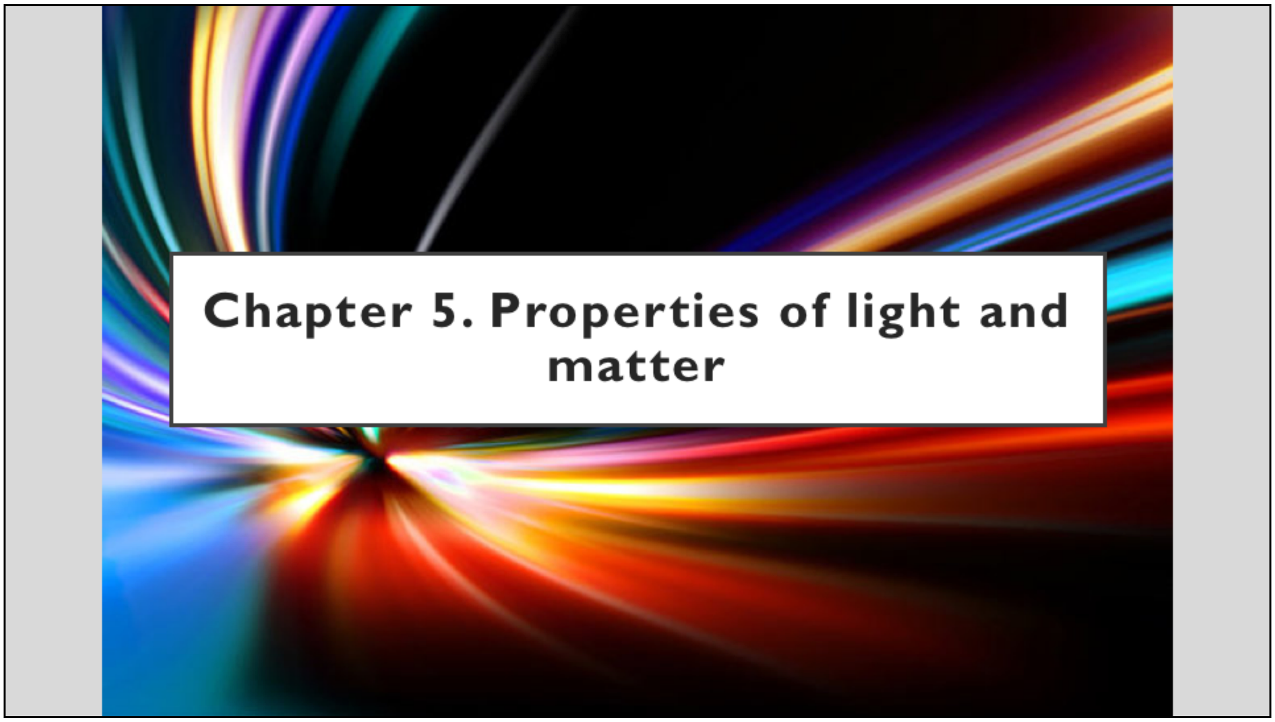
- The Earth's rotation makes it an oblate spheroid shape
- Gravitational forces between the Earth and the Moon also add to Earth's bulge (~1m in water, ~30cm in rock) as do
- Gravitational forces between the Earth and the Sun (about half as much as the Moon's effect)
  - These forces can work together, or not
  - As the Moon and Sun can deform the Earth, so the Earth deforms the moon
    - Remember Jupiter's moon Io: F_g pulls from Jupiter, Ganymede, and Europa have made Io volcanically active



http://www.slate.com/blogs/bad_astronomy/2008/09/08/ten_things_you_dont_know_about_the_earth.html

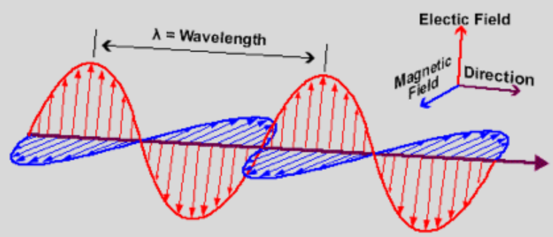
Also

http://www.slate.com/blogs/bad_astronomy/2006/08/30/when_i_say_centrifugal_i_mean_centrifugal.html


Chapter 5. Properties of light and matter

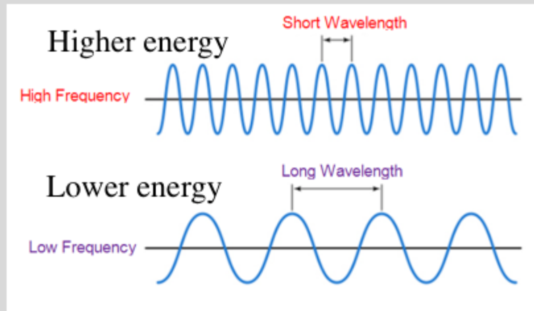
What is light?

- We talked about fields: magnetic, electric, gravitation
- The discovery of the electromagnetic nature of light
- Light is a perturbation, a disturbance, traveling (propagating) through electric and magnetic fields.
- Light behaves like both a wave and a particle
- Properties of waves:
  - Wavelength
  - Frequency
  - Amplitude



Behavior of light

- Light is emitted
- It can be absorbed, transmitted, reflected, diffracted, scattered, and it can interfere
  - Scattering depends on size of scatterer (molecules in atmosphere, clouds) and the wavelength of the light
  - Blue efficiently scattered in atmosphere, red not



Light can have

Why are plants green?

A. It's complicated
B. All light except green is absorbed, and green light gets reflected so that's what we see
C. Plants absorb some of the green, just not all of it; since the Sun peaks in green wavelengths, it would be too much for the plants
D. Not all plants are green, don't generalize like that, Prof A

Why are plants green?

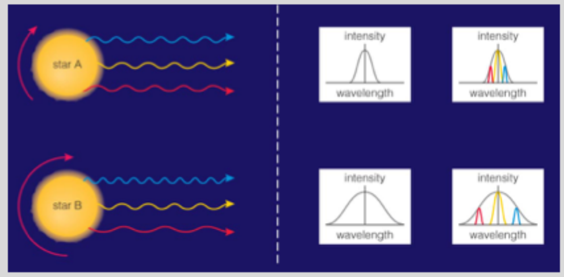
The colors we see are light at those wavelengths being reflected back at us. It's weird and counterintuitive that plants would reflect back the light the Sun sends us the most of, but there is a point where it's just too much light and it could be damaging to plants.

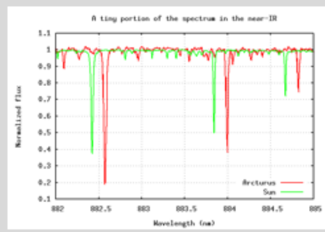
On planets around cooler stars, say peaking in red light, would plants be red?

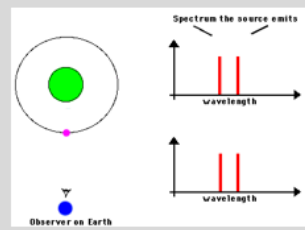
A. It's complicated
B. All light except green is absorbed, and green light gets reflected so that's what we see
C. Plants absorb some of the green, just not all of it; since the Sun peaks in green wavelengths, it would be too much for the plants
D. Not all plants are green, don't generalize like that, Prof A

Doppler shift

- The apparent change in wavelength of a wave when the source is moving
  - Example: an ambulance. Tone changes as it passes you, but if you're inside, it stays the same
  - Example from class: if I'm snapping (or carrying a metronome) while walking toward you, as I get closer, you hear the snap sooner because the sound doesn't have to travel as far to get to you
- If waves seem compressed (higher energy, bluer), then *blueshifted*
- If waves seem spread out (longer wavelength, redder), then *redshifted*

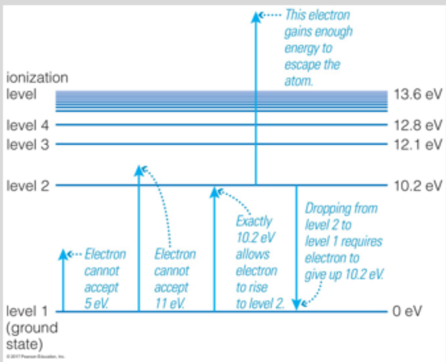


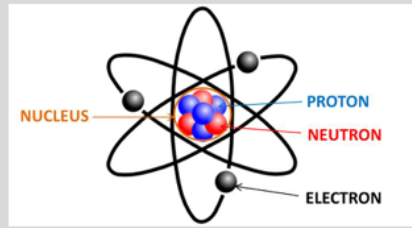




Atoms

- Electrons have energy
  - Discrete **energy levels** possible
  - Can gain or lose energy, but only in specific (quantized) amounts

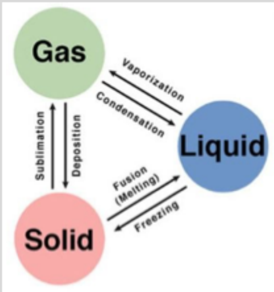


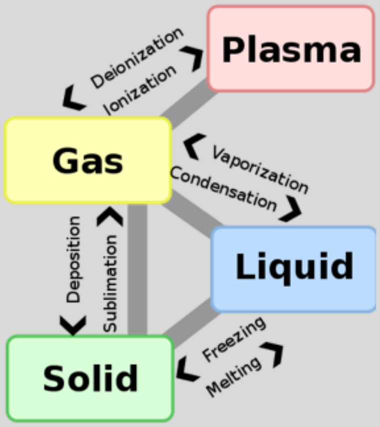


- Photons and atoms can exchange energy
  - Emission or absorption
- The larger the change in energy level, the more energetic the absorbed or emitted photon!
- Energy level transitions are an element's spectroscopic "fingerprint"

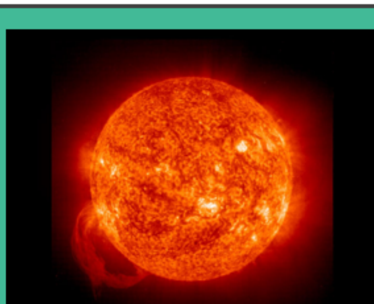
Phases of matter

- Beyond the boiling point?
  - Can break up molecules: molecular dissociation
  - Adding even more energy can free electrons from atoms: ionization
    - Ion: an atom with some net charge (either positive or negative)



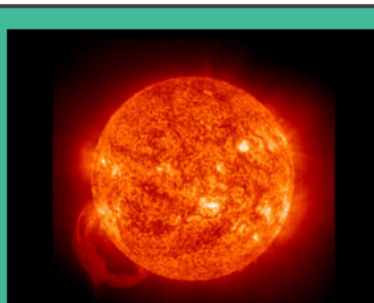


What happens when you increase the temperature of (add more energy to) a gas?



A. Molecules can break up into atoms
B. Electrons can escape atoms
C. The gas becomes a plasma
D. All of the above

What happens when you increase the temperature of (add more energy to) a gas?



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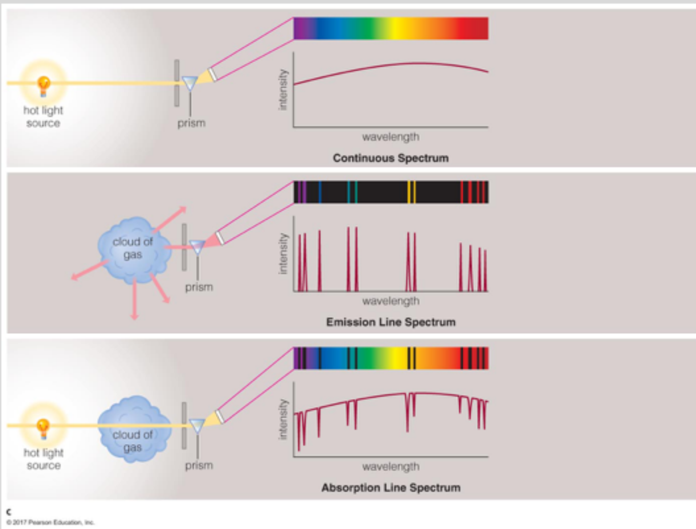
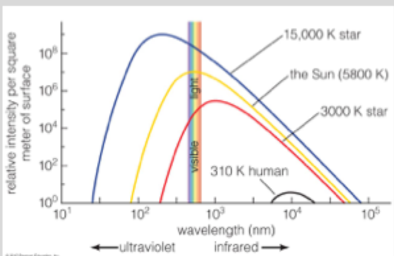
Spectra



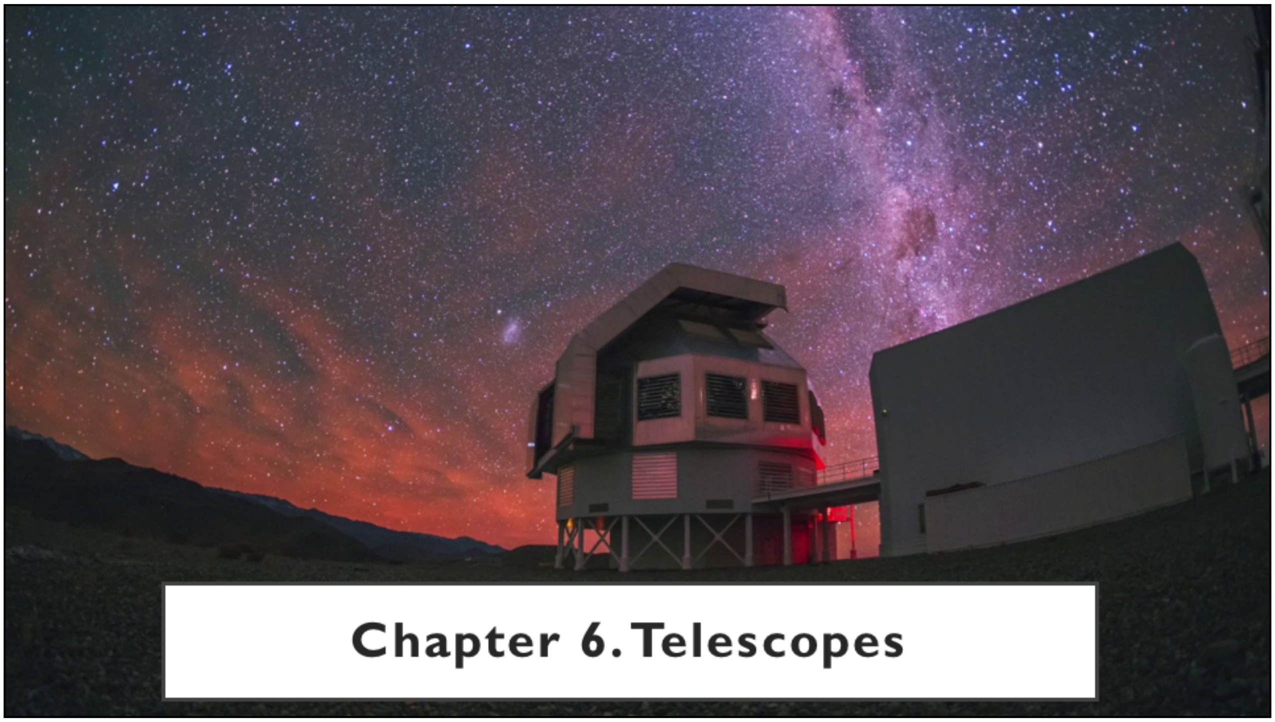
- Incandescent bulbs produce continuous spectra
- Clouds of gas (or gas in tubes, heated by a lamp!) produce emission spectra
- A continuous source behind a cloud (like the Sun's core surrounded by its outer atmosphere) produces an absorption spectrum

Two laws of thermal radiation

- Stefan-Boltzmann law
  - When you look at the same size piece of thermally emitting objects, the hotter object always emits more light at all wavelengths
    - Can see this in curves below



- Wien's law
  - Hotter objects emit photons with higher average energy
    - The peak of the intensity curves move bluer as objects are hotter
    - Affects color of an object. Example: the Sun peaks around green wavelengths


Chapter 6. Telescopes

Observing and recording

- Light sensors…
  - Eyes
  - Telescopes
- and recorders
  - CCDs

- Telescopes are characterized by 2 key properties…

What are the two key properties that telescopes are characterized by?

A. Whether they refract or reflect and if they have a CCD attached
B. Their light-collecting area and their angular resolution
C. How many lenses/mirrors they have and where the light is focused
D. Their angular resolution and how long the focal length is

What are the two key properties that telescopes are characterized by?

A. Whether they refract or reflect and if they have a CCD attached

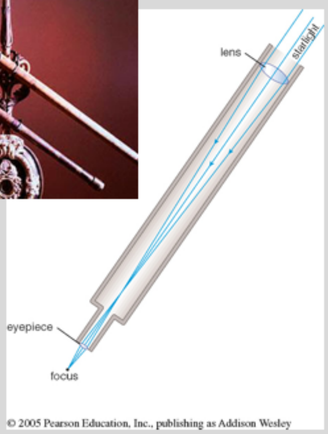
B. Their light-collecting area and their angular resolution

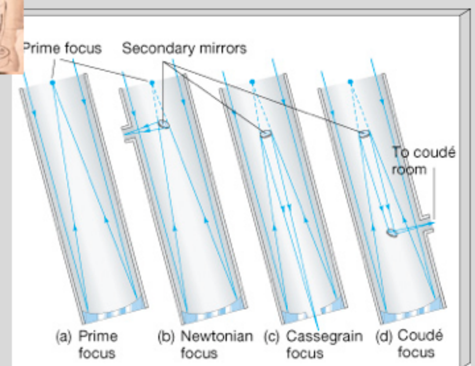
C. How many lenses/mirrors they have and where the light is focused

D. Their angular resolution and how long the focal length is

Telescope design

- Refracting vs reflecting





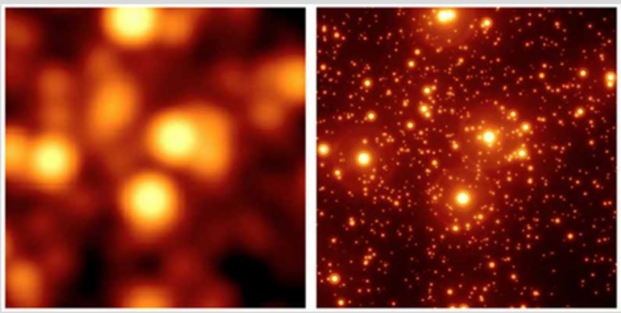
What are telescopes and their instruments used for?

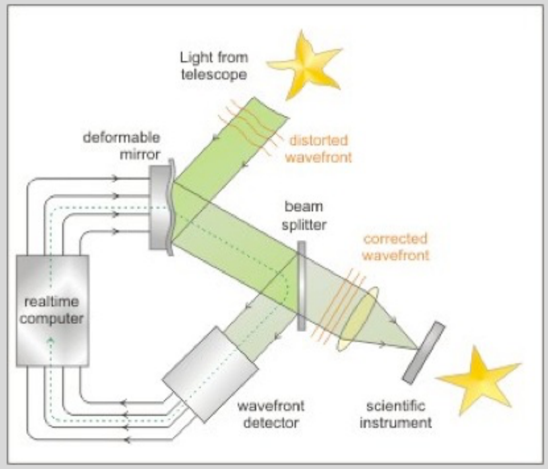
- Imaging
- Spectroscopy
- Studying time-variations of objects

- We can observe a very wide range of the electromagnetic spectrum, not just visible light!

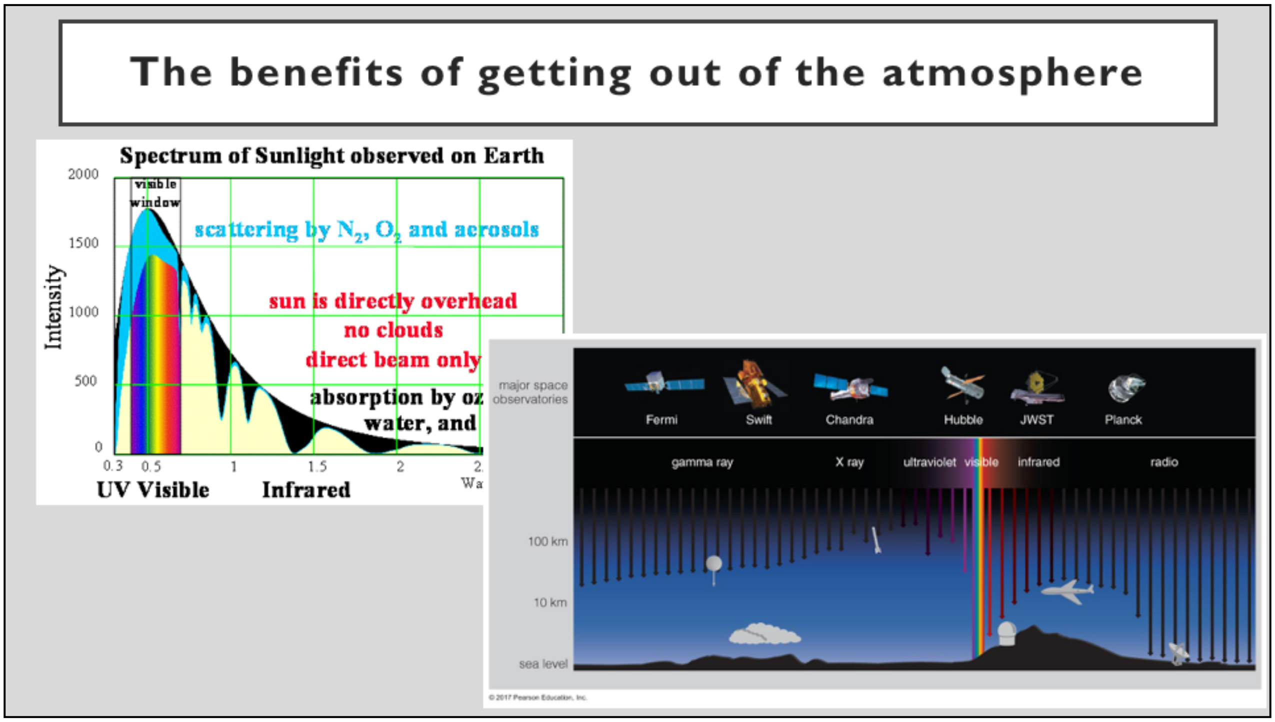
Adaptive optics

- Uses a guide star (sometimes a fake guide star, a laser) and a deformable mirror to correct for atmospheric turbulence





http://www.astronoo.com/en/articles/adaptive-optics.html
http://davide2.bo.astro.it/ter5/ter5/ao_eng.html



Why would we want to leave Earth's atmosphere to look at the Universe?

https://web.calpoly.edu/~rfield/Thermalstructure.htm