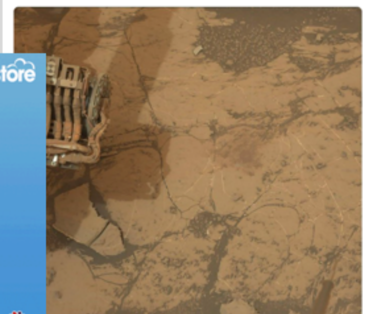
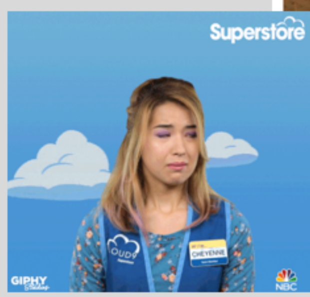
Today in science…

- Rover update
  - Still waiting for Oppy to wake up!
  - Impassioned twitter campaign imploring NASA to keep listening began yesterday…
  - Why?
  - Funding probably threatened- how long should we listen before declaring Oppy's mission over?

SarcasticRover
@SarcasticRover

Its hard to do work when your friend is missing. Actually, it's always hard to do work, because work sucks - but now it's harder. #SaveOppy #WakeUpOppy





Definitely follow sarcasticrover on twitter.. Really, really funny!


The nature of science and the scientific method
$\Sigma F = ma$
H_2
CO_2
C_2H_5
H_2O

What, how, and why?

- What do you think a scientist does?
- How do we do science?
- Why do we science?

Give me two examples!

http://obs.carnegiescience.edu/Magellan

Terminology

- Data – properties, generally measured, of processes or phenomena

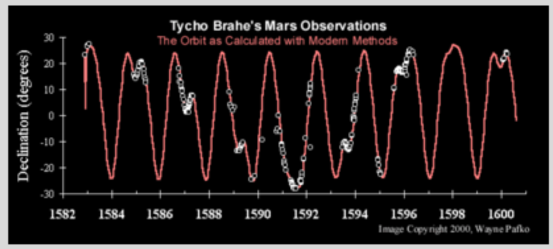
  - Example: positions of planets in the sky (properties) demonstrating their motion (process/phenomenon)

Date	Longitude
1990 Sep 06	63°
1990 Sep 15	67°
1990 Sep 25	71°
1990 Oct 05	74°
1990 Oct 15	75°
1990 Oct 25	74°
1990 Nov 04	72°
1990 Nov 14	68°
1990 Nov 24	66°
1990 Dec 04	62°
1990 Dec 14	59°
1990 Dec 24	58°
1991 Jan 03	57°
1991 Jan 13	59°
1991 Jan 23	60°
1991 Feb 02	63°
1991 Feb 12	67°

Most trivial hill I'm willing to die on: the word 'data' is plural (singular, 'datum'). So while it sounds odd, saying "those data look great" is grammatically correct!

Terminology

- Data – properties, generally measured, of processes or phenomena
- Observation – data collection without interfering with the phenomenon
  - Example: Tycho Brahe's lovely observations of Mars: all together, a data set.



http://www.pafko.com/tycho/observe.html

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

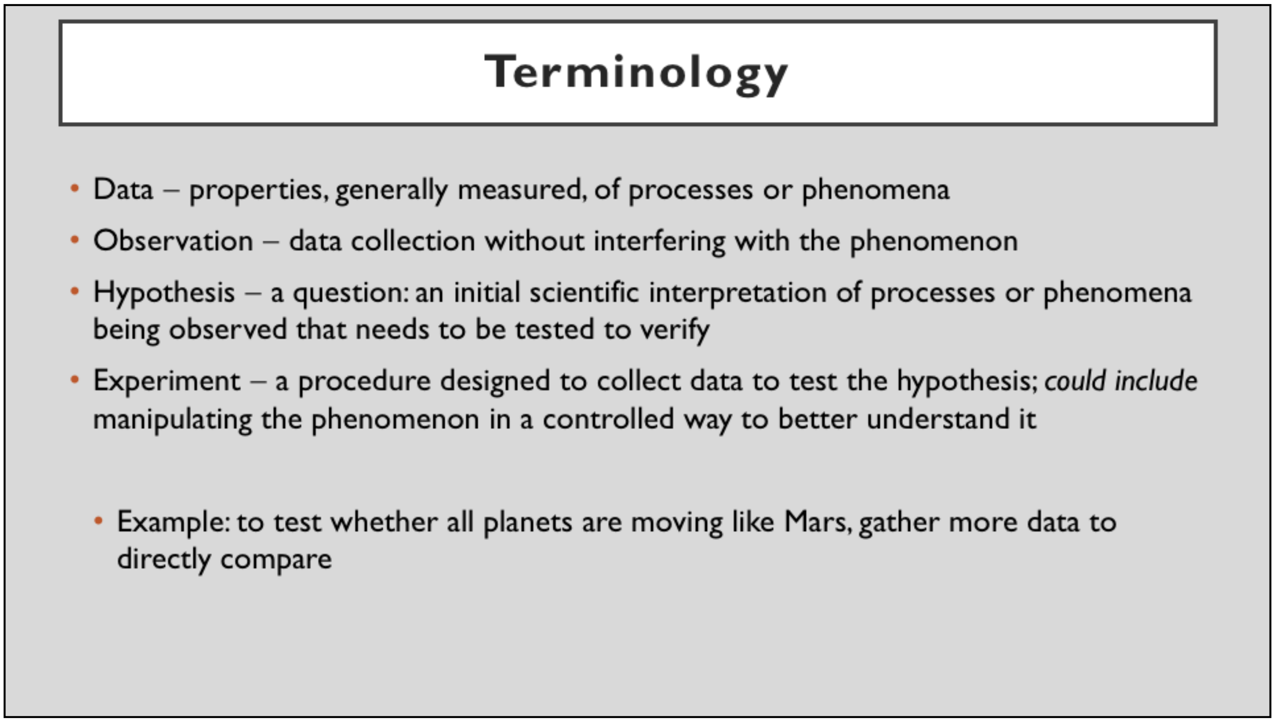
  - Example: we've seen planets move in the sky, and think we understand what Mars is doing. Are all the planets revolving around the Earth?

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; manipulating the phenomenon in a controlled way to better understand it

Experimental astrophysics? Or observational?

- Think/pair/share!
- By the definitions I just gave for an observation and an experiment, can astrophysicists actually do experiments? Or can we only make observations?
  - Observation – data collection without interfering with the phenomenon
  - Experiment – a procedure designed to collect data to test the hypothesis; manipulating the phenomenon in a controlled way to better understand it



So let's update that to *could include* manipulating the phenomenon in a controlled way to better understand it

For astronomers, looking at large samples of stars or planets is in itself a kind of experiment: I can't make one star hotter to see how it changes, but I can look at a hotter star and compare it to a cooler star

Terminology

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- 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
  - Example: epicycles to explain Mars' retrograde motion in the sky

Terminology

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- 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.

Science!

- Science…
  - Seeks explanations for observed phenomena that rely on natural causes
  - Progresses through creation and testing models of nature that explain observations as simply as possible
- A scientific model must make testable predictions. If the predictions do not agree with the observations, the model must be revised! That's science.

- What do scientists argue about?
  - Usually, whether the experiment
    - Was the right approach to answer the question being asked
    - Included all possible variables that could have impacted the outcome
  - Or, whether the question asked from the beginning was the right one to be asking

If this is all so clear-cut and objective, then what do scientists even argue about?

Sometimes, multiple interpretations can fit the same data set

Other times, there are disagreements on the question being asked, the way it is asked, the setup of an experiment– whether it answers the questions being asked, or if something has been neglected that should not have been.

The scientific method

- The scientific method is an approach, a framework for asking and trying to answer questions, for better understanding the Universe
- **<u>The major steps of the scientific method:</u>**
  - 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!

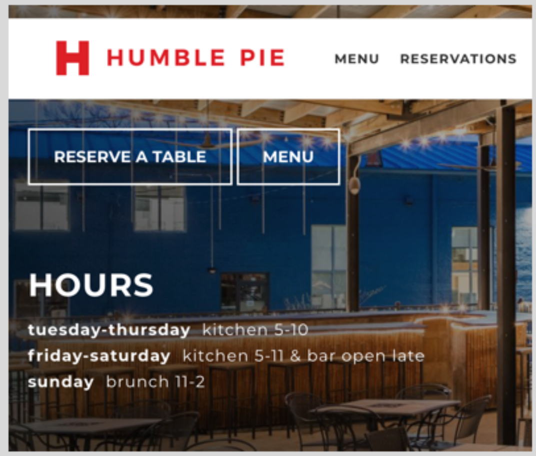
The more you know, the more you know you don't know.

Things we know, and things we know we know

- Science is a living body of information
  - Knowledge that originates from observations, formulation of models to explain observations, and testing to see if models are correct
  - We believe in science because of rigor: we test and retest, gather more information, and rule out reasonable possibilities
- *"Common sense"* is not a valid argument
  - There are things we know without having subjected them to rigorous, scientific testing. That's ok: intuition often even motivates and helps science, but should not be used in its place as justification

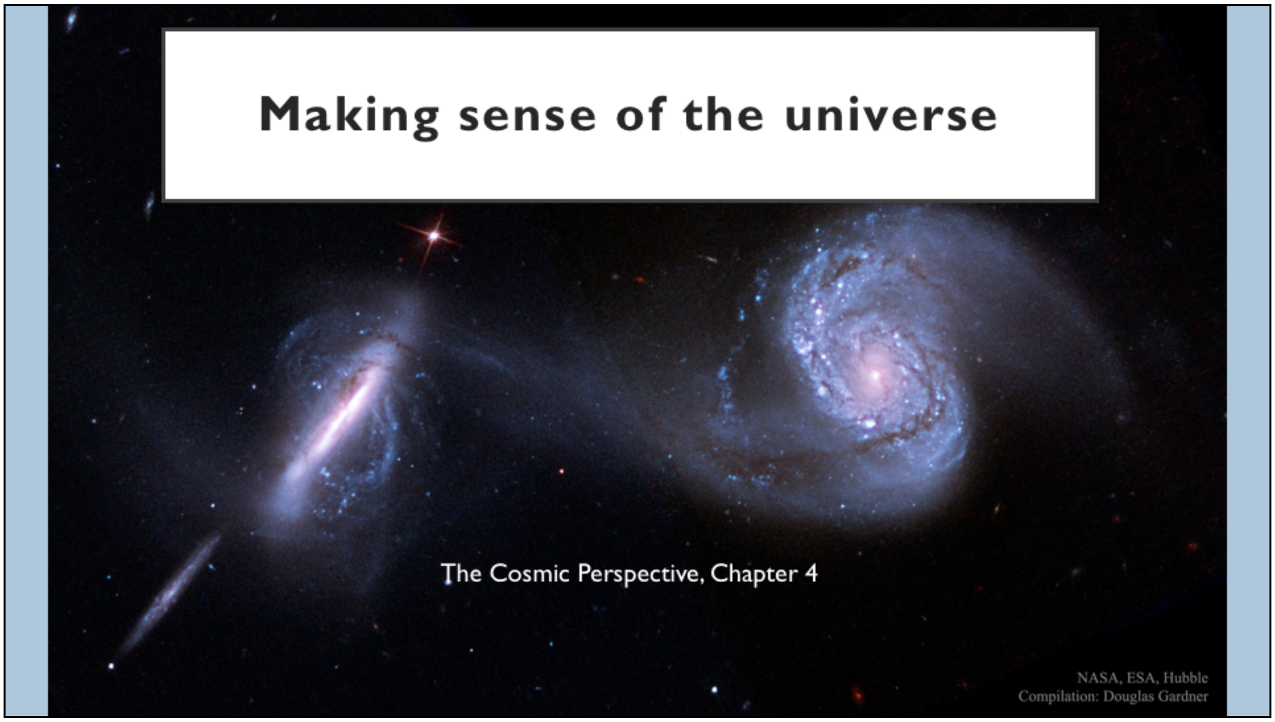
Validity of a Scientific Theory

- 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!)



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

Understanding motion

- Consider this mutt. How might we describe her and her blurry motion?
  - Where she is
    - x,y,z position in the yard
  - How fast she's going
    - Her speed
  - Which way she's going
    - direction
  - If she's slowing down or speeding up
    - Acceleration or deceleration

What we'll be covering in this chapter…

We do these kinds of calculations, watching, guessing, extrapolating, every single day. When you drive, you have a feel for where someone might go or when you'll be able to make your turn just based on a few observations, a few data points, in your head. Let's put some words to those data you take automatically

Speed, velocity, and acceleration

- Say you're in the car.
  - You have some distance to travel
  - In some amount of time
  - Your (average) **speed** is how far you travel in that time
  - Units: familiarly, mph or mi/hour
    - Metric: m/s

Speed, velocity, and acceleration

- **Velocity** tells you both your speed and direction

- Most of Yoshi's speed is in the forward direction, but he's steering a little to the left, too, for upcoming turn
- What you don't want in this level is any speed downward…
- Velocity also has units of m/s, is usually denoted **v**

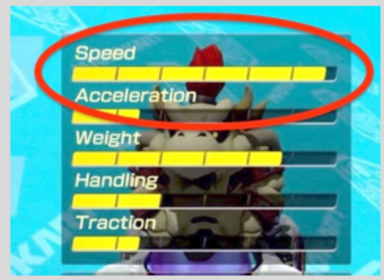
Speed, velocity, and acceleration

- **Acceleration**, denoted **a**, is a change in velocity over time
- Units: Velocity change/time = (m/s) / s = m/s²

$$a = \frac{v_f - v_i}{t}$$

v_i – initial speed
v_f – final speed
t – time interval

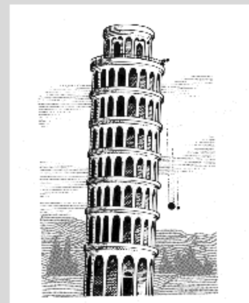
- To accelerate, your speed, or direction, or both can change
- Acceleration can be negative (deceleration)



Dry Bowser is fast, but ouch- once he hits something… huuuuge deceleration penalty

Acceleration due to gravity

- According to legend, Galileo dropped weights from atop leaning tower of Pisa
  - Objects fall at the same rate, regardless their mass: they experience the same acceleration
  - Acceleration due to gravity on Earth will increase an object's speed by 9.8 m/s for every second the object is falling
  - Denoted as lower-case g
    - $g = 9.8 m/s^2$



(corrected units on g)

Momentum and force

- **Momentum** is the product of an object's mass and velocity, denoted p
  - p = mv
  - Two objects of very different mass can have the same momentum if their velocities are different
  - In same direction as object's velocity

Momentum and force

- Mario's kart has a decent top speed
- Acceleration is ok; important for starting off the line and recovering from impacts
- Mario+Kart weight is a little high
- Traction and handling are good; it'll help him where other karts may lose the best line through the corners
- Top speed and high weight = more momentum!
  - If hit by kart with less momentum, will experience less deceleration than other kart
- Good acceleration = if hit, can recover from abrupt deceleration more quickly

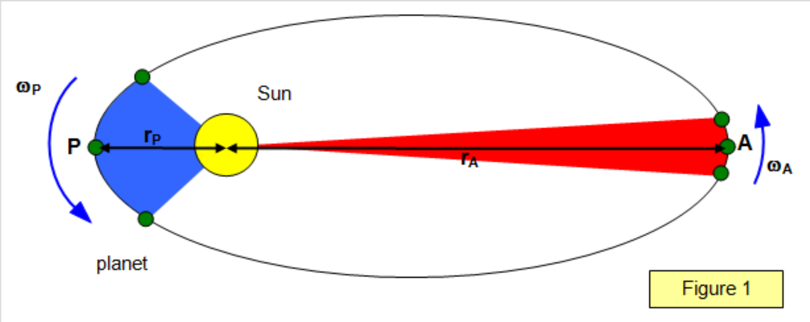
Momentum and force

- **Momentum** is the product of an object's mass and velocity, denoted p
  - p = mv
  - Two objects of very different mass can have the same momentum if their velocities are different
  - In same direction as object's velocity
- **Force**, applied for some amount of time, can change an object's momentum if the force is great enough
  - Consider Mariokart: if you're Yoshi, why don't you want to be hit on the track by Donkey Kong or Bowser?
- The **net force** on an object is the sum of all the forces acting on an object
  - Forces are vectors and have directions
  - You can be experiencing forces in opposite directions yet the net force can be 0

Ok, this has been momentum and force along straight lines.. How is this relevant to astronomy? Next up… orbits

Momentum in orbits

- Momentum when moving along a curved path: **angular momentum**
  - Angular momentum due to rotation: *rotational* angular momentum
  - Due to path in an orbit: *orbital* angular momentum



http://www.schoolphysics.co.uk/age16-19/Mechanics/Rotation%20of%20rigid%20bodies/text/Angular_momentum_and_keplers_laws/index.html

Momentum in orbits

- Momentum when moving along a curved path: **angular momentum**
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- Angular momentum can also be changed by applying a force- that force is called **torque**
  - in cars (or, Mariokarts), torque is used to describe how the car's engine and drive train can change the angular momentum of the wheels against the ground
  - how effective an applied torque is depends on how far from the rotation axis it's applied

Mass vs weight

- **Mass** is a fundamental measure of the amount of matter in an object
  - Mass is measured with a balance
  - Unit of mass: g (in US system, our unit of mass is called a slug)
- **Weight** is the downward force exerted by an object of a particular mass under acceleration due to gravity
  - Weight is measured with a scale
  - Unit of weight: newtons (lbs, in our daily lives)

Free-fall and weightlessness

- Free fall happens when there is nothing to *prevent* you from falling- no force acting against your downward motion
  - Good example: you go sky diving, voluntarily, because you wanted to*
  - Scary example from the book: you're in an elevator and the cable snaps*

  - *note: there isn't an absence of forces when you're skydiving.. Air resistance is a big one, but it's not stopping you from falling, just slowing you down a little
  - *note: elevators are really really safe and this basically never happens

*

Sir Isaac Newton (1642-1727)

- Newton graduated college and left Cambridge about when the plague hit
- Sitting around one day, he had a realization that shattered a thousand years of thought or so

- Aristotle believed laws governing motion on Earth were distinct and different from those governing motion of stars, planets
- United view of Earth and heavens into one Universe; beginning of modern astrophysics

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

- This probably seems somewhat obvious: a parked car on a flat surface isn't going to just roll away

Unless the parking brake is off, it's in neutral, and someone pushes it

Newton's Laws of Motion

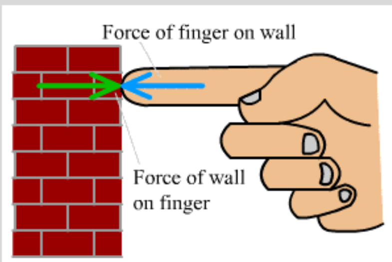
1. In the absence of a net force, an object in motion or at rest remains in motion or at rest
2. Force = mass × acceleration (F = ma)

- Possibly the most profound of all three laws; what it is saying is that *force* is the *rate of change of momentum*.

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

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 $\times$ acceleration ($F = m \times a$)
3. For any action (applied force) there is an equal and opposite reaction (force)

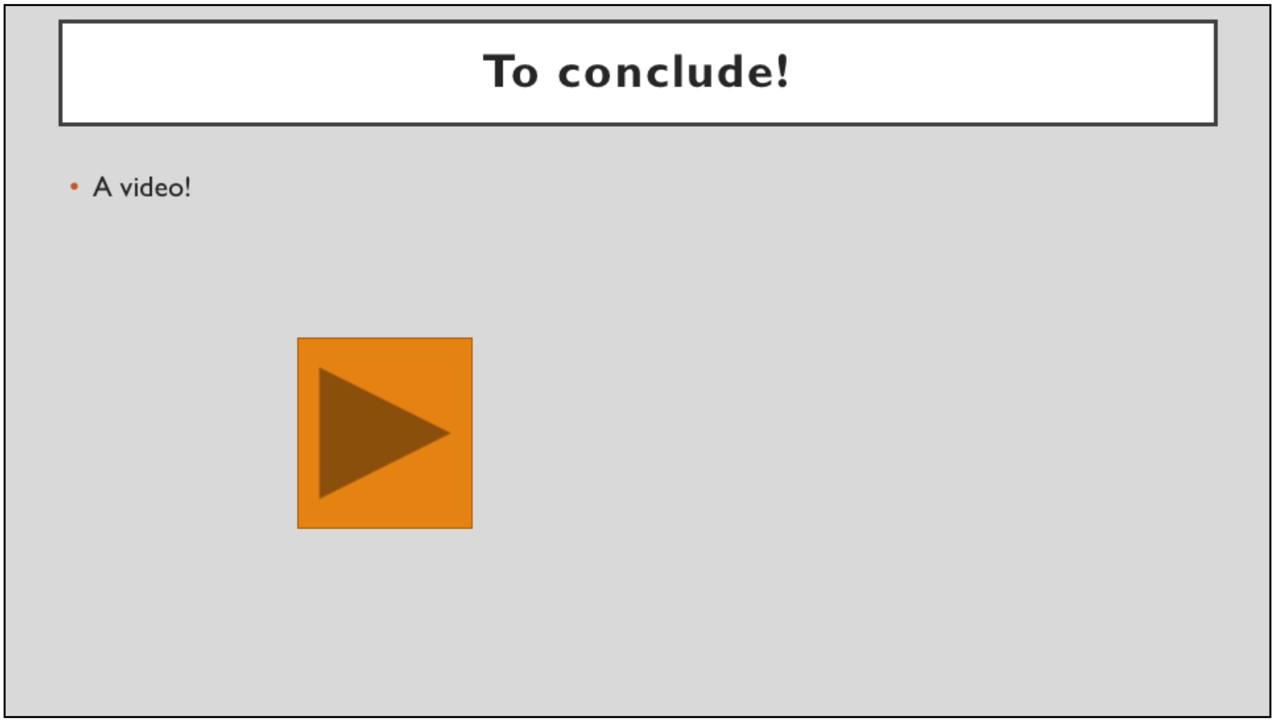


Recall that acceleration is the change in the velocity per unit time- if you regroup the terms in the equation, you get a change in momentum per time; that’s what force is

There's a video coming after logistical notes, don't pack up yet

Logistical notes

- Check your clicker quiz grades on Canvas- I may have left you a note if you only answered 1/3 or 2/3 of the questions! Was your Clicker malfunctioning?
- No office hours today, apologies!
- Lab 1 due today at 11:59pm
  - Median completion time: 30 minutes!
  - If Stellarium isn't working: 2 computers in Physics Library with program
  - There is a web version, but it doesn't automatically play in time, you have to set date/time
    - https://stellarium-web.org/#/
- Chapter 2 homework due 9/1



https://www.youtube.com/watch?v=D6_UVBAfdHA&frags=pl%2Cwn

Stop at the 8 minute mark