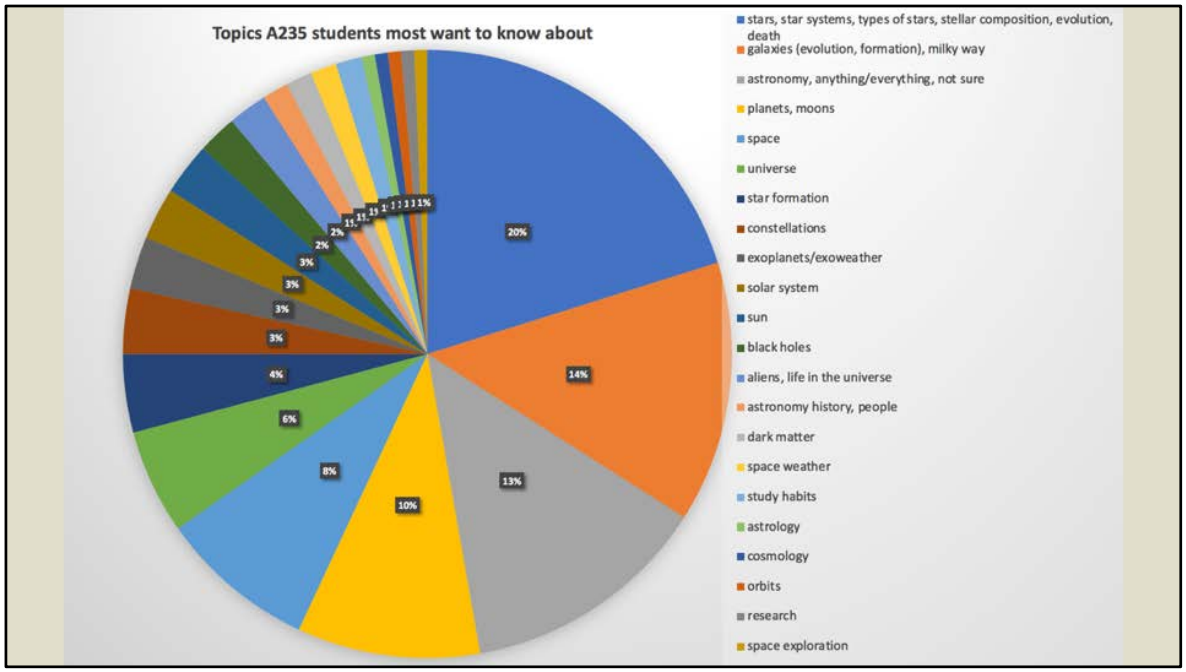


Remind class to do an info sheet if there for first time

Logistical notes

- **Assignment 1: Tutorial on how to use Mastering Astronomy, due by 1/21, 11:59pm. Average time: 23 minutes**
- **Assignment 2: Chapter 1, due by 1/24, 11:59pm. Average time: 46mins**

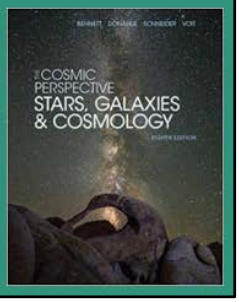
Try to do homeworks as early as you possibly can, they have tutorials, animations, and helpful info- not just questions.

Access MasteringAstronomy through Canvas!

This is our textbook →

Clickers will be handed out on Tuesday

Planetarium on Thursday—more details Tuesday



Here is a link to a video on how to get to mastering astronomy through canvas and getting the access code that way- it's already linked, so you shouldn't need the Course ID:
https://www.youtube.com/watch?v=NlbR6zpdKRQ&feature=youtu.be

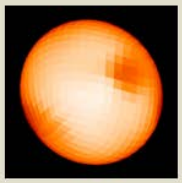
Survey says...

- Would you like to give feedback on this class? Would you like to earn some cash for doing so? Are you 18 or older?
- Lindsay is doing a research project: Tracking Students' Reactions to Elements of an Introductory Astronomy Course

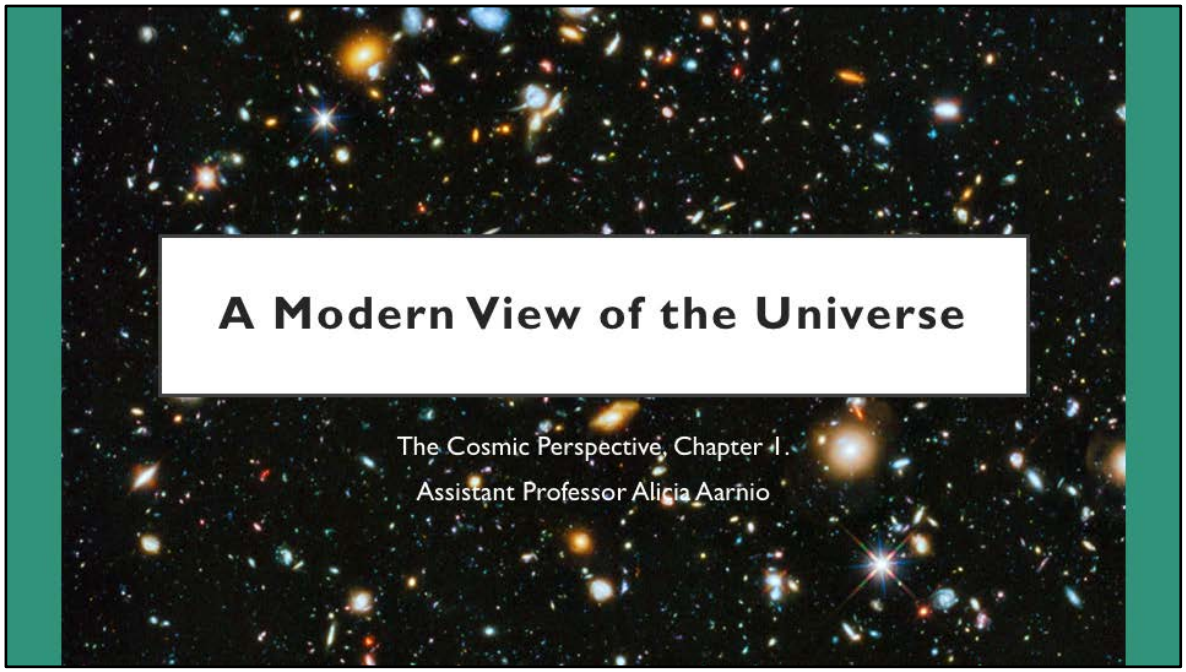
- Text "astro" and your UNCG email address to (336) 265-7183

Today in science…

- Is it a planet? Or.. No?
- Gliese 581D discovered in 2007
- Astronomers have gone back and forth since, trying to tell if it's a planet or spots on the host star
- (yes! Stars have spots too, just like the Sun!)

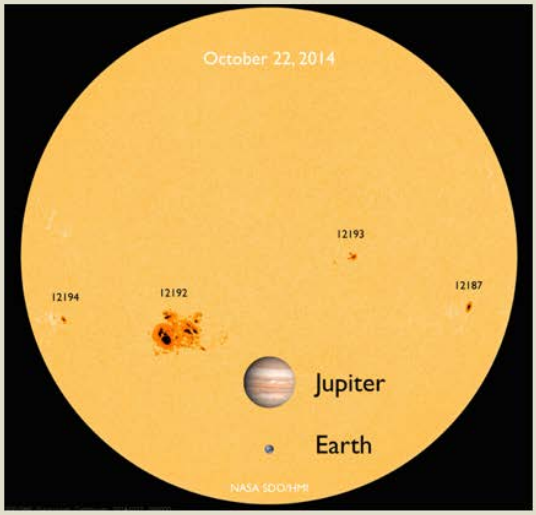


https://en.wikipedia.org/wiki/Gliese_581d
https://arxiv.org/abs/1709.10107


A Modern View of the Universe
The Cosmic Perspective, Chapter 1.
Assistant Professor Alicia Aarnio

Astronomical Definitions

- Star
  - Large
  - Hot
  - Made of gases
  - Generates heat and light through nuclear fusion in their cores



Let's start with the Solar System..
Page 4 in your text
https://wattsupwiththat.com/2014/10/22/solar-flare-danger-massive-sunspot-the-size-of-jupiter-takes-aim-at-earth/
Star: large, hot ball of gas that generates heat and light through nuclear fusion

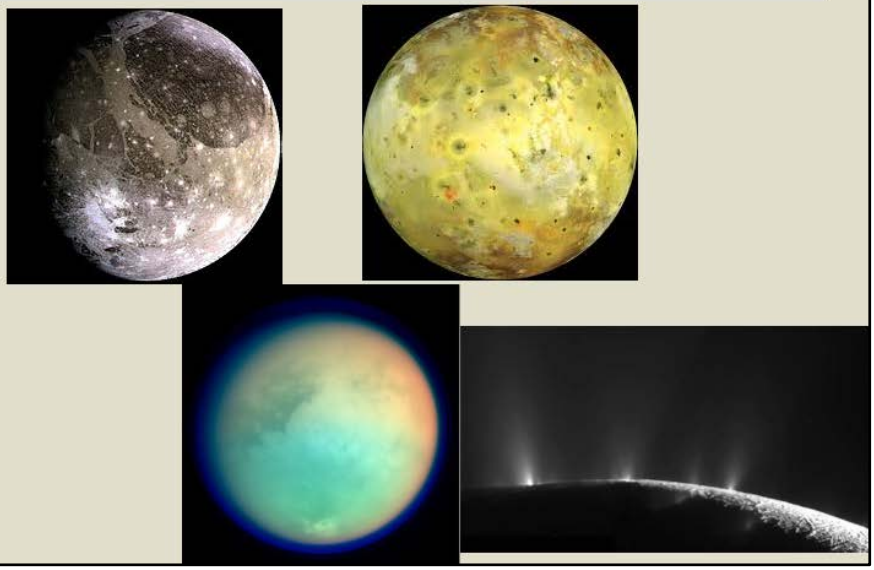
Astronomical Definitions

- Star
- Planet
  - Orbiting a star
  - Could be rocky, icy, gaseous (or a mix!)
  - Large enough to be round

https://arstechnica.com/science/2014/09/images-come-down-as-maven-and-mom-get-to-work-at-mars/
https://www.nasa.gov/feature/goddard/2016/hubble-captures-vivid-auroras-in-jupiter-s-atmosphere
Planet: a body orbiting a star that could be rocky, icy, or gaseous; moderately large, enough so that when it formed, it became round

Astronomical Definitions

- Star
- Planet
- Moon/satellite
  - Orbits a planet

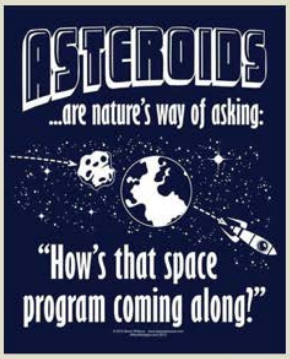


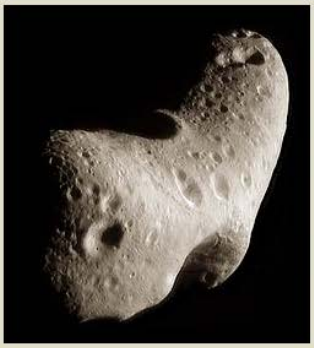
https://en.wikipedia.org/wiki/Ganymede_(moon)
https://en.wikipedia.org/wiki/Io_(moon)
https://www.space.com/11604-saturn-moon-titan-impacts-atmosphere.html
http://planetary-mechanics.com/tag/cassini/

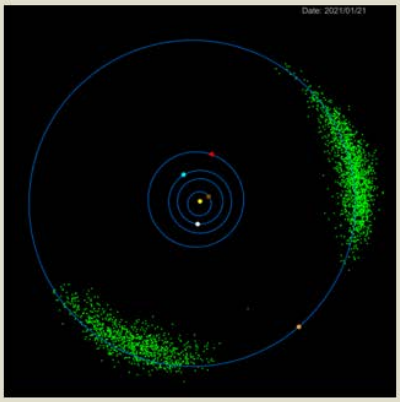
Moon/satellite: orbits a planet

Astronomical Definitions

- Star
- Planet
- Moon/satellite
- Asteroid







https://en.wikipedia.org/wiki/433_Eros
https://www.nasa.gov/content/goddard/lucy-the-first-mission-to-jupiter-s-trojans
Asteroid: a rocky body that orbits a star

Astronomical Definitions

- Star
- Planet
- Moon/satellite
- Asteroid
- Comet
  - Small
  - Rock & ices
  - Elliptical or hyperbolic orbits
  - Ices evaporate close to Sun, making tail

https://www.space.com/19878-halleys-comet.html
Comet: small body, rocky, but with frozen interiors. They're typically on elliptical orbits that take them close enough to the sun to heat up and sublimate (go straight from ice to gas); the gases released are the 'tails' we observe

Astronomical Definitions

- Galaxy
  - Collection of:
    - Stars, stellar systems, gas, orbiting a massive center
  - Held together by gravity

https://www.nasa.gov/content/hubble/grand-swirls-from-nasas-hubble
Galaxy: a collection of stars, star systems, and gas held together by gravity, orbiting around a massive center

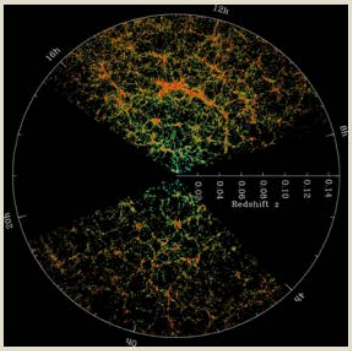
Astronomical Definitions

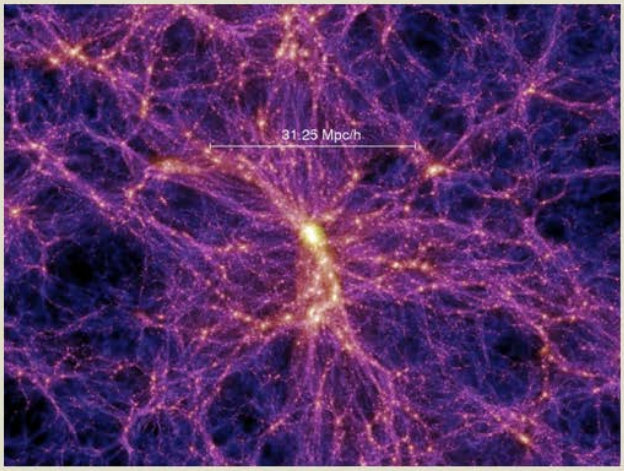
- Galaxy
- Cluster of galaxies
  - A few: group
  - 100s to 1000s: cluster
  - More? Supercluster!

https://www.universetoday.com/30522/galaxy-cluster/
Cluster of galaxies: anywhere from a few (a group) to hundreds to thousands of galaxies bound together by gravity

Astronomical Definitions

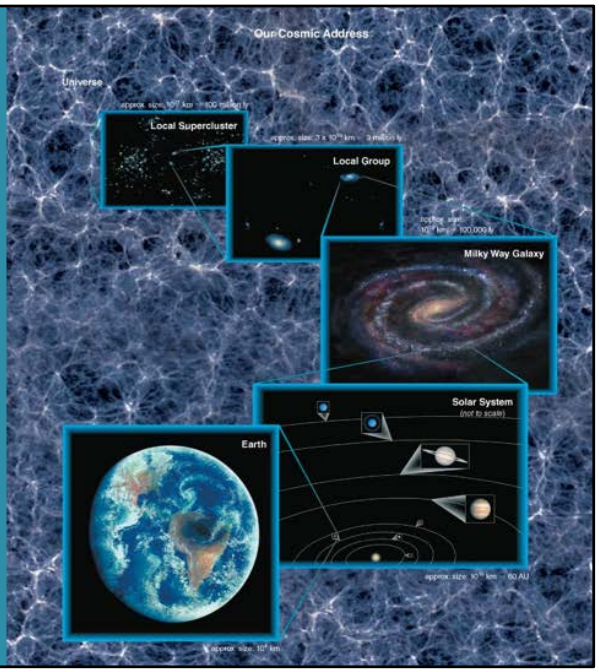
- Galaxy
- Cluster of galaxies
- Universe, observable universe
  - Everything, everything we can observe





https://wwwmpa.mpa-garching.mpg.de/galform/virgo/millennium/
Universe: all matter and energy, the sum total of it all
https://www.e-education.psu.edu/astro801/content/l10_p6.html
Observable universe: what we can observe from Earth, likely a very small fraction of the actual universe

What is our place in the Universe?



What do we see when we look up?
https://www.universetoday.com/74190/what-is-the-name-of-our-galaxy/

What do we see when we look up?
https://www.universetoday.com/74190/what-is-the-name-of-our-galaxy/

What is a light year?

Light year (LY)

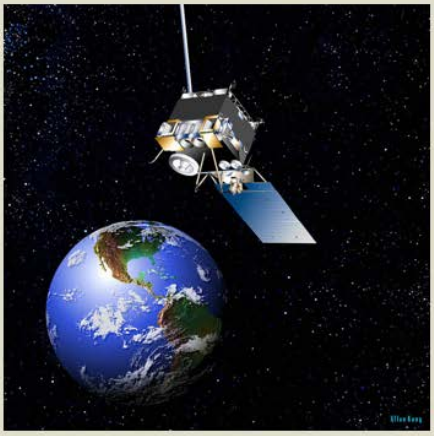
- The distance the light travels during 1 year
- Speed of light abbreviated as **c**
  - ***c = 2.99x10^8 m/s = 670 million mph!***
- 1 LY =
  - speed × time =
  - c × t =
  - (3x10^5 km/s) × (365.24 days) × (24 hours) × (60 minutes) × (60 s) = 9.46 trillion km
  - Convert to AU:
  - 9.46x10^{12} km ≈ 63,000 au

1 AU is 1.496e+8 km

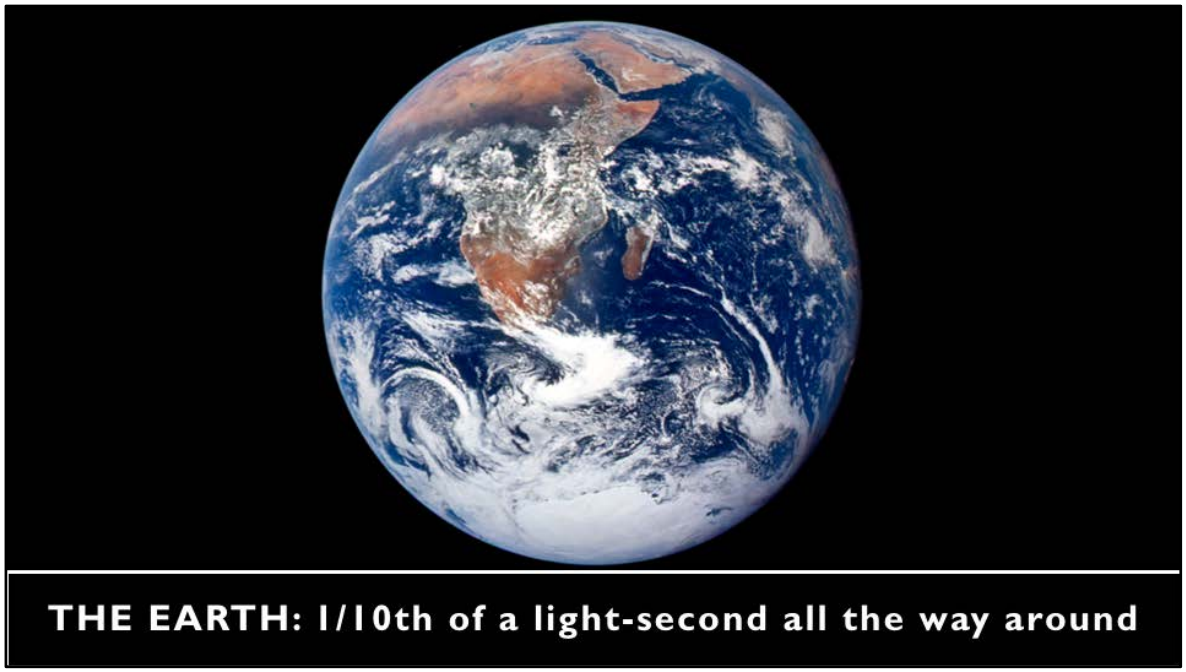
See mathematical insight 1.3 for more information on dimensional analysis and order-of-magnitude techniques

What is a light year?

- Important figure of merit: The Sun is 8.3 light-minutes away from the Earth
  - …what does this mean for us?
  - This is a limit on space weather forecasting warning time!

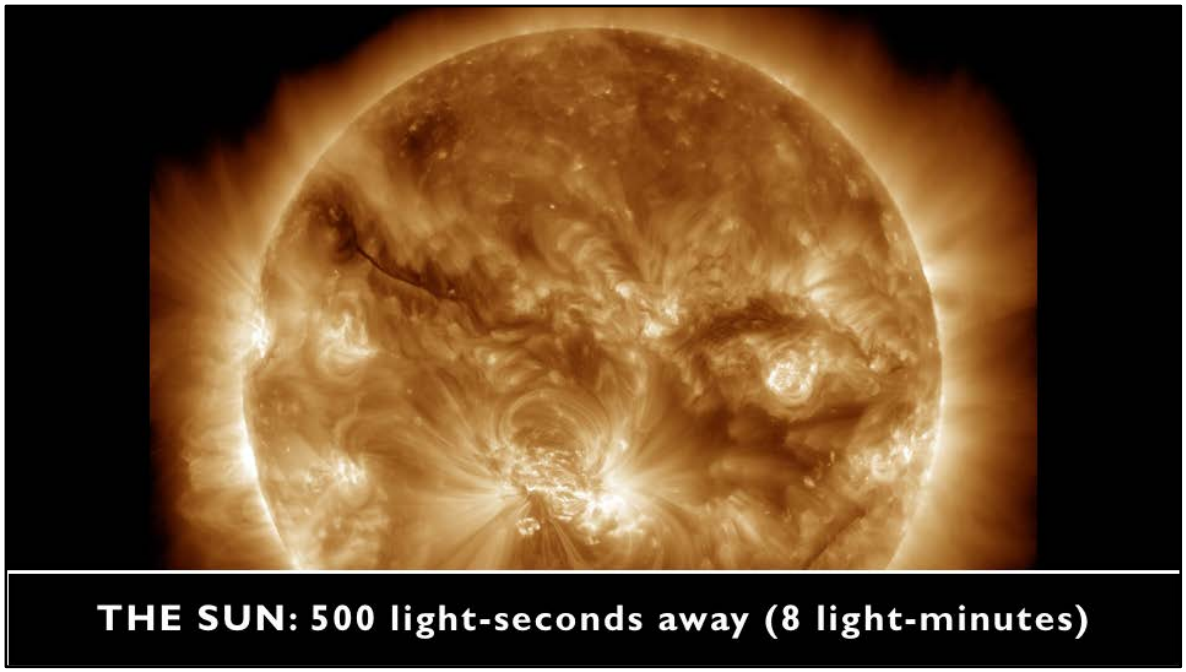


It means we only have, at most, 8 minutes' warning if the Sun is doing something we need to be worried about! The speed of light is the fundamental limit, the fastest that information can travel.
GOES stands for Geostationary Operational and Environmental Satellite, it's keeping an eye on the Sun and on the Earth for us
Image is of GOES 13:
https://www.nasa.gov/directorates/heo/scan/services/missions/earth/GOES13.html
--> we're currently on GOES-R, the 16th satellite in the GOES mission series



The circumference of Earth is 24,901 mi

THE MOON: 1 light-second away



Aka 1 AU!

In other units, Jupiter is 5.2 AU from the Sun (on average)

9.6 AU from the Sun (on average)

39.5 AU from the Sun (on average)

Scale of the Solar System

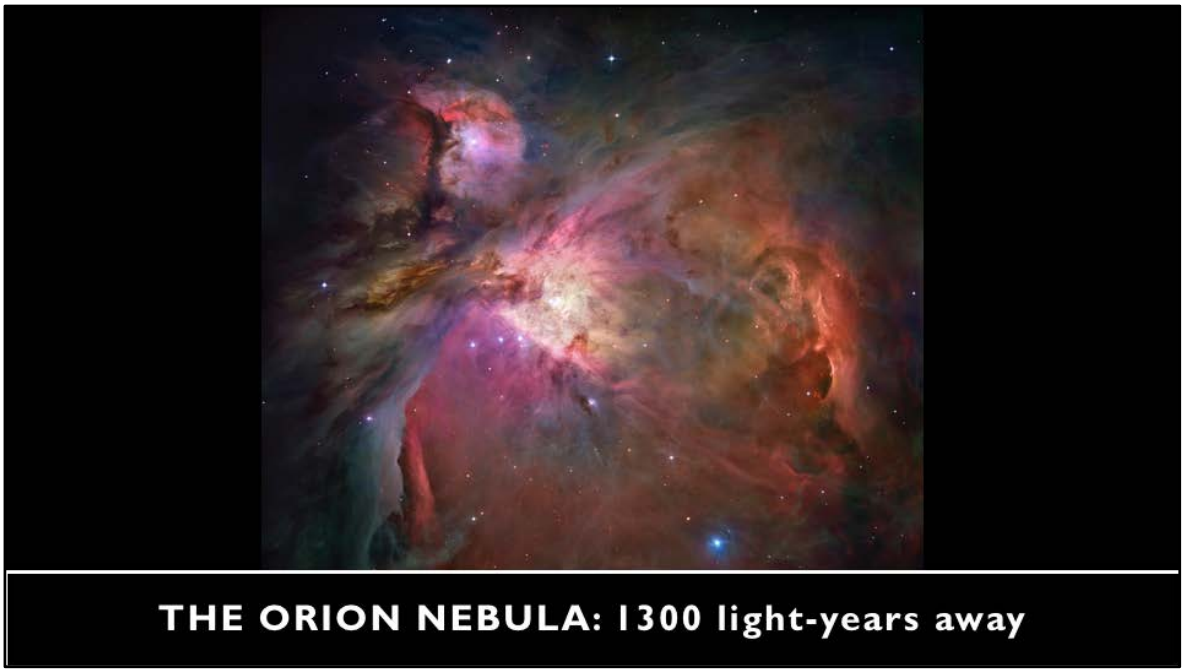
Let's build a 1 : 10,000,000,000 solar system

Sun	grapefruit
Mercury	salt/sand grain 19 feet away
Venus	peppercorn 36 feet away
Earth	peppercorn 49 feet away
Mars	big salt / small pepper 75 feet away
Jupiter	marble 250 feet away
Pluto	head of pin 1/3 mile away

25

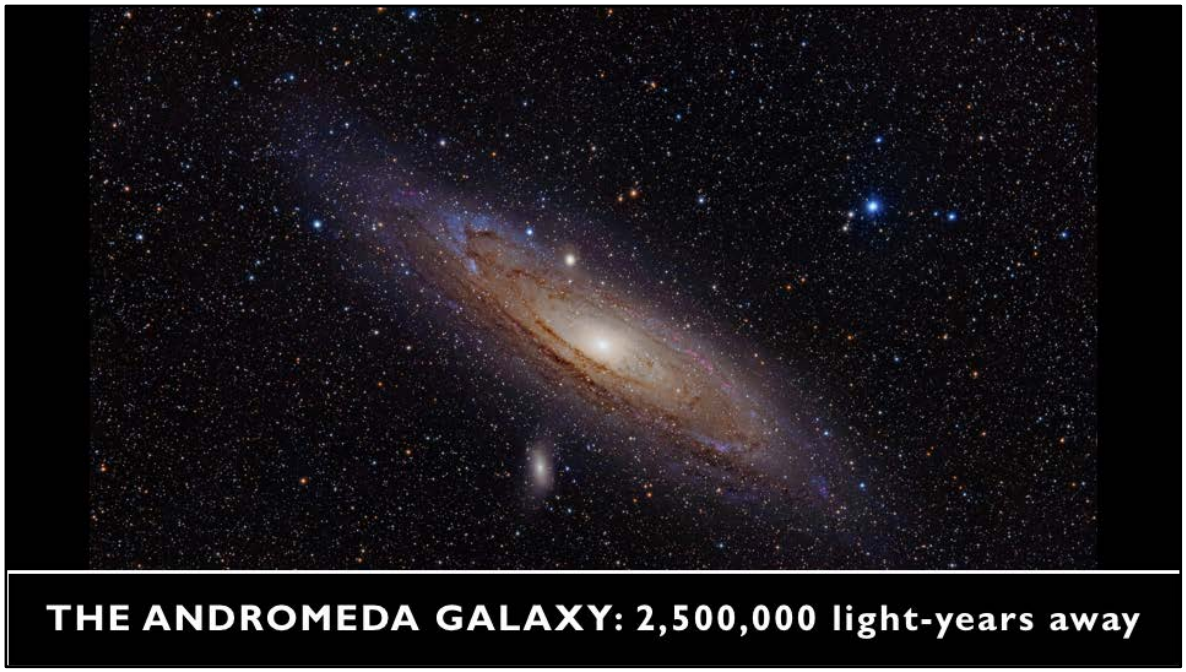
4 light years is 252,964 LY. For things this far away, it's easier to use a unit like LY than AU

BETELGEUSE: 600 light-years away



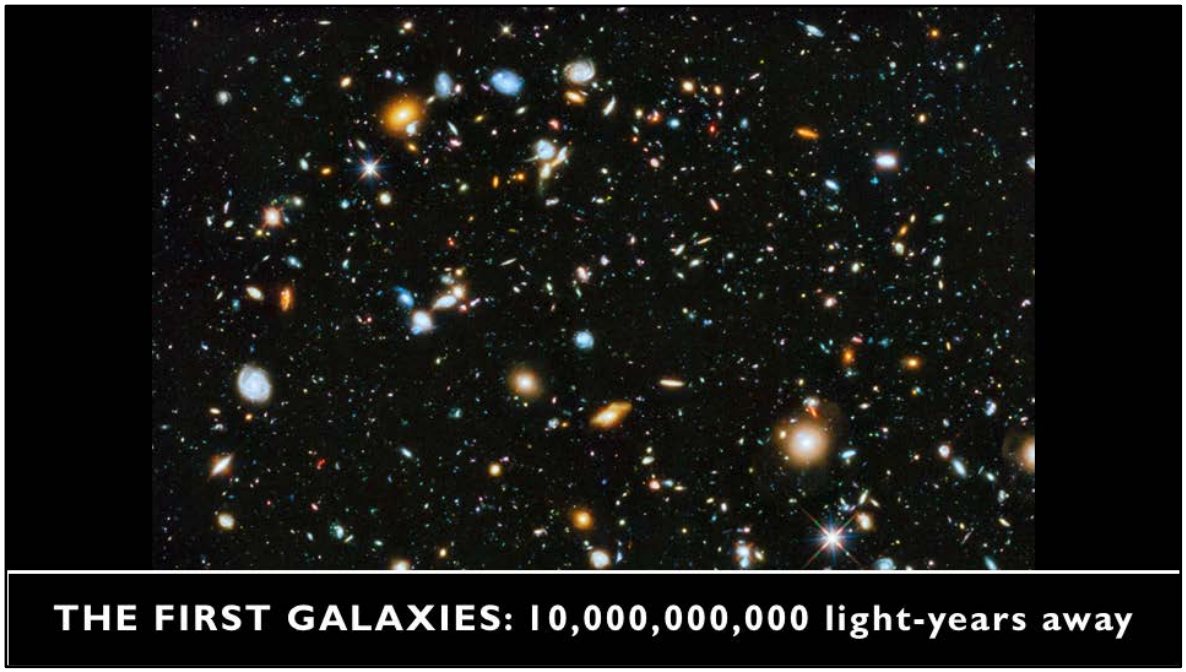
THE ORION NEBULA: 1300 light-years away

THE MILKY WAY'S CENTER: 25,000 light-years away

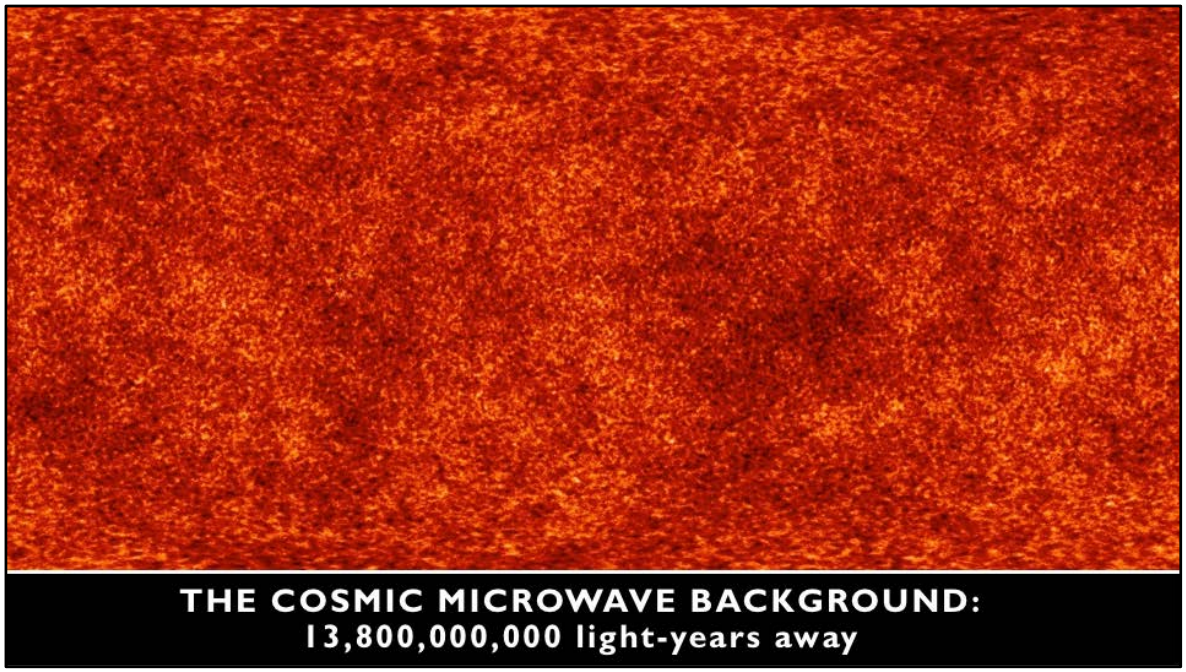


THE ANDROMEDA GALAXY: 2,500,000 light-years away

THE WHIRLPOOL GALAXY: 25,000,000 light-years away



THE FIRST GALAXIES: 10,000,000,000 light-years away



THE COSMIC MICROWAVE BACKGROUND:
13,800,000,000 light-years away

Far away means back in time

- Light travels at a finite speed (300,000 km/s).

Destination	Light travel time
Moon	1 second
Sun	8 minutes
Sirius	8 years
Andromeda Galaxy	2.5 million years

- Thus, we see objects as they were in the past:

The farther away we look in distance, the further back we look in time.

History of the Universe

Our Cosmic Origins

- Big Bang – beginning of the Universe: ~14 billion years ago
- Galaxy groups/clusters are flying away from each other

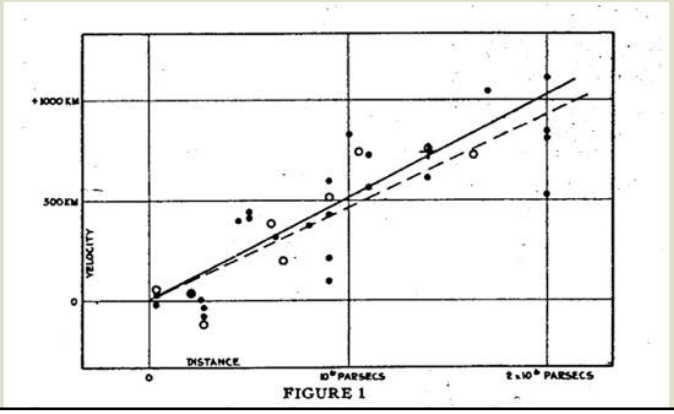
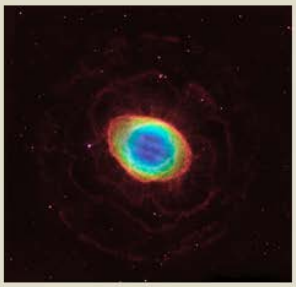


FIGURE 1

Bonus material: why do we believe the Big Bang happened?
http://astronomy.swin.edu.au/cosmos/b/big+bang
This cheerful gent, going by the name Edwin Hubble, observed the farthest galaxies from us are moving faster than those closest
https://apod.nasa.gov/diamond_jubilee/1996/hub_1929.html

Our Cosmic Origins

- Big Bang – beginning of the Universe: ~14 billion years ago
- Galaxy groups/clusters are flying away from each other
- No expansion within galaxies
- Only hydrogen & helium in the early Universe
- All other elements were created inside stars
- We are all created from the star stuff
- Current composition of the Sun: 70% H, 28% He, 2% others



Remember this planetary nebula from the first lecture? All that material it sloughed off is rich with heavy elements that helps make us who we are!
https://www.nasa.gov/mission_pages/hubble/science/ring-nebula.html

The Cosmic Calendar

You may or may not know, our textbook is broadly inspired by the Cosmos TV series (the original, not the remake).. Even the book title!

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

Most of what we know is <u>SO</u> recent!

It was just a hot cosmic second ago that Kepler and Galileo demonstrated a heliocentric picture: we orbit the Sun, not the other way around

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


Spaceship Earth
Our motions in space and time
*not the one at Epcot..

Section 1.3

Cosmic Motions

- As we sit/stand here…
  - Earth is rotating

https://www.youtube.com/watch?v=PIedt8uOxCE

Cosmic Motions

- As we sit/stand here…
  - Earth is rotating
  - We're orbiting the Sun

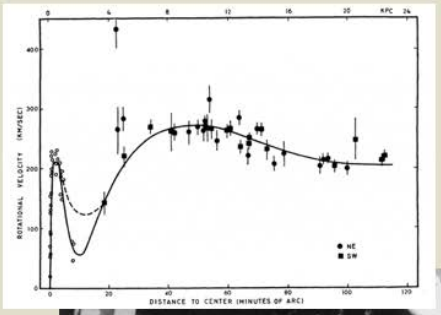
https://www.youtube.com/watch?v=_QcgDiF1a14

Cosmic Motions

- As we sit/stand here…
  - Earth is rotating
  - We're orbiting the Sun
  - The Sun is orbiting the Milky Way

Galactic rotation, dark matter

- How do we know galaxies rotate?
  - Observe how smaller parts of them move!
  - Compare those observations to physics



- What's weird about galactic rotation is one of Astronomy's biggest, neatest mysteries
  - Who predicted it? Fritz Zwicke
  - Who observed it? **Vera Rubin and W. Kent Ford, Jr.**

Hidden figure alert! Vera Rubin passed away in late 2016, passed over year after year for the Nobel prize in Physics. I was lucky enough to know her, she was a lovely, kind, and brilliant person. https://en.wikipedia.org/wiki/Vera_Rubin
http://adsabs.harvard.edu/abs/1970ApJ...159..379R → the actual paper published in 1970
https://astrobites.org/2016/12/27/how-one-person-discovered-the-majority-of-the-universe-the-work-of-vera-rubin/

Cosmic Motions

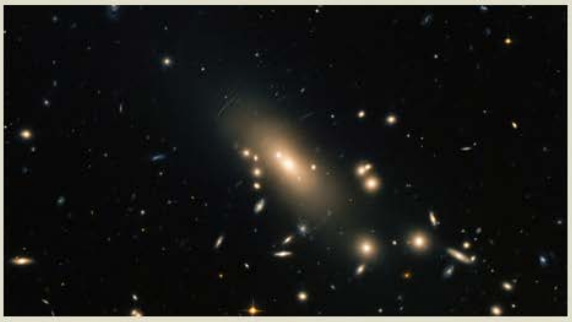
- As we sit/stand here…
  - Earth is rotating
  - We're orbiting the Sun
  - The Sun is orbiting the Milky Way
  - The Milky Way is moving in the Local Group
    - Galaxies in the local group aren't moving away from us

Our nearest (large) galactic neighbor, Andromeda →

The Magellanic Clouds are technically dwarf galaxies, and closer to us than Andromeda

Cosmic Motions

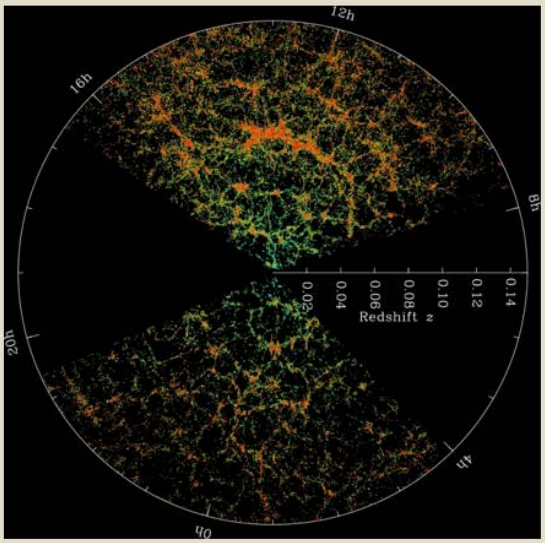
- As we sit/stand here…
  - Earth is rotating
  - We're orbiting the Sun
  - The Sun is orbiting the Milky Way
  - The Milky Way is moving in the Local Group
  - The Local Group is part of a Supercluster of galaxies



I'm not showing a picture of the Milky Way, or the cluster of galaxies it's in.. Why not?
https://scitechdaily.com/hubble-views-galaxy-cluster-abell-1413/

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

The human adventure of astronomy

Practical, social, technological shifts

- Practical applications:
  - navigation
  - calendar systems
- A driver of revolutions in:
  - social change and thought
  - our perception of the planet (round!)

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!

Practical, social, technological shifts

- Practical applications
  - navigation
  - calendar systems
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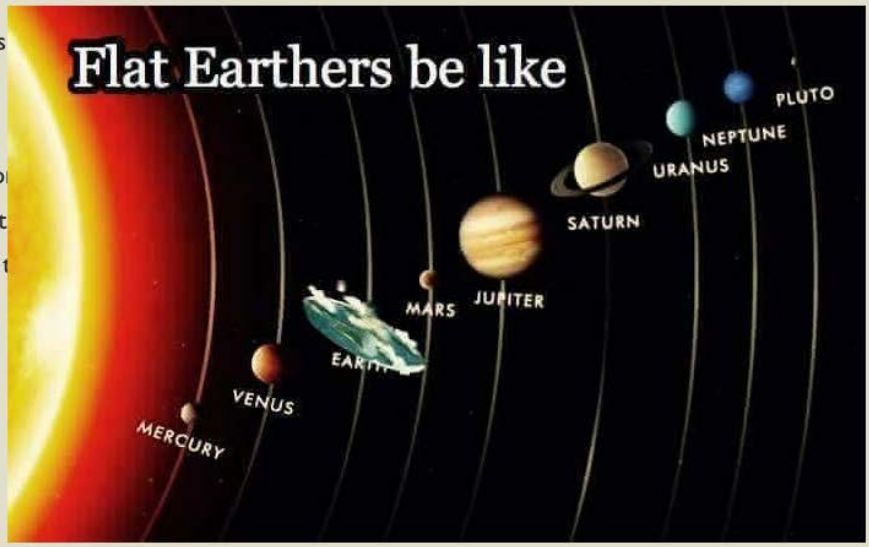
  - social change and t
  - our perception of t



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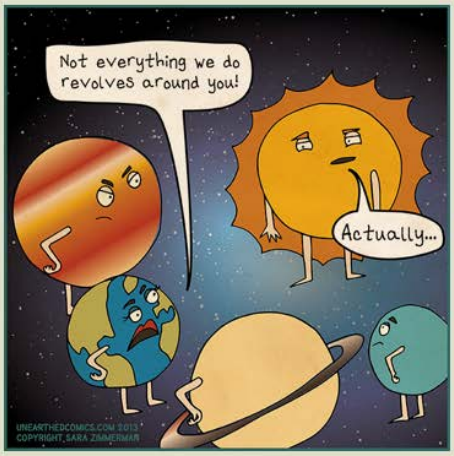
Practical, social, technological shifts

- Practical applications:
  - navigation
  - calendar systems
- A driver of revolutions in:
  - social change and thought
  - our perception of the planet (round!)
  - in the Universe (it doesn't revolve around the Earth)



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Practical, social, technological shifts

- Practical applications:
  - navigation
  - calendar systems
- A driver of revolutions in:
  - social change and thought
  - our perception of the planet (round!)
  - in the Universe (it doesn't revolve around the Earth)
- Huge advances in technology
  - Newton's laws laid foundation for the industrial revolution
  - space travel
  - computation

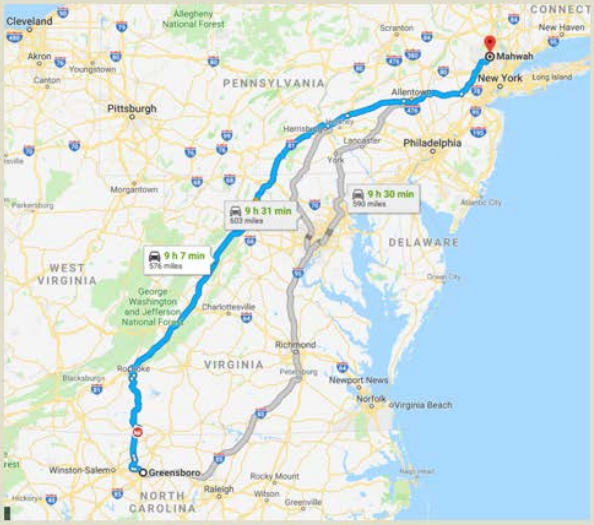
Copernicus proposed a heliocentric view in 1543. Galileo, Brahe, and Kepler made the observations that proved it; Galileo was put under house arrest by the church for heresy in 1633. Galileo was forgiven officially py Pope John Paul II in 1992!

Recap!

- The scale of the Universe: almost inconceivably vast. Expand out and continually have to convert distance scales: m, au, light years, parsecs, redshift
- History of the Universe: a lot happened before we got here! Big bang, expansion, a generation of star formation, we were born of star stuff (metal enrichment by end of stars' lives)
- Spaceship Earth: we rotate and orbit a body (the Sun) that is rotating and orbiting a body (the Milky Way) that is rotating and orbiting a cluster (the Local Group) that is along for the ride with a body (a galaxy Supercluster) that is part of a filament in the expanding universe
- The human adventure of astronomy: has shaped how we think about the Earth, its place in the Universe, and exploration. Driver of social change, technological advancement

Quick math problem…

- Chapter 1 homework asks you to do some unit conversions… you have all done this before, whether you realized it or not!
- Let's say, *entirely hypothetically*, you were driving from Greensboro to New Jersey.



Quick math problem…

- Let's also say, *entirely hypothetically*, your trusty steed is a 2006 Nissan Sentra that gets about 31mpg.
- You'd like to know how many times you'll need to stop for gas on the trip (and if you can time those stops well for the *hypothetical* pup in the back seat)
- One more piece of info needed: said Sentra also has a gas tank capacity of 12 gallons.

A hypothetical sentra dented by students in CU boulder parking garage… thanks for that :P