

## **(Logistical note/demo: MasteringAstronomy)**

**★ Assignment 1: Tutorial on how to use Mastering Astronomy, due by 8/23, 11:59pm. Average time: 23 minutes**

**★ Assignment 2: Chapter 1, due by 8/22, 11:59pm.  
Estimated time: 51 mins**

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

I'll open up homeworks at noon the day they're assigned. You'll have 1 week to complete, after due date you can still do them for half credit.

## Today in science...

**"Academic writes 270 Wikipedia pages in a year to get female scientists noticed"**

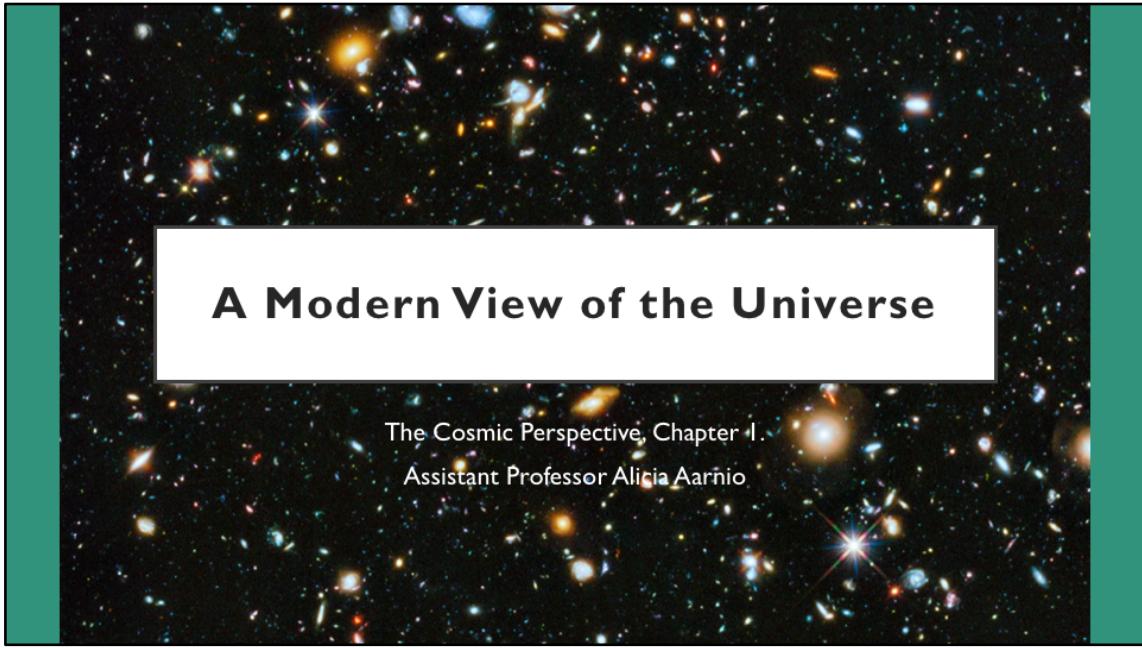


- <https://www.theguardian.com/education/2018/jul/24/academic-writes-270-wikipedia-pages-year-female-scientists-noticed>

- In 2011, 90% of Wikipedia contributors/editors surveyed identified as male and white
- Who the contributors are affect what the content is you read!
- Dr. Jess Wade
- [https://en.wikipedia.org/wiki/Emma\\_McCoy](https://en.wikipedia.org/wiki/Emma_McCoy)
- [https://en.wikipedia.org/wiki/Susan\\_Goldberg](https://en.wikipedia.org/wiki/Susan_Goldberg)
- [https://en.wikipedia.org/wiki/Kim\\_Cobb](https://en.wikipedia.org/wiki/Kim_Cobb)

<https://www.theguardian.com/education/2018/jul/24/academic-writes-270-wikipedia-pages-year-female-scientists-noticed>

Article about the effects of authorship on wikipedia and potential for biased content:  
<http://journals.sagepub.com/doi/10.1177/2053951715614332>



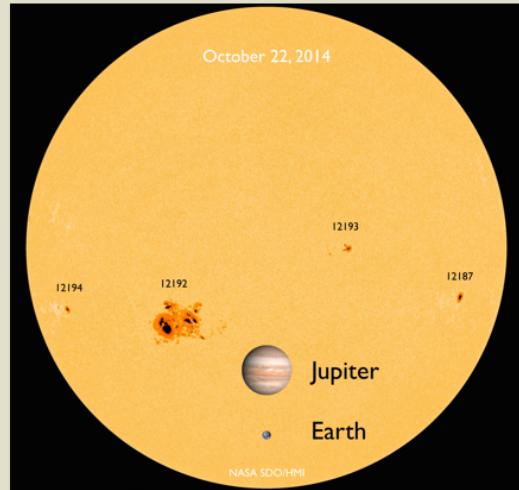
# A Modern View of the Universe

The Cosmic Perspective, Chapter 1.

Assistant Professor Alicia Aarño

## 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..

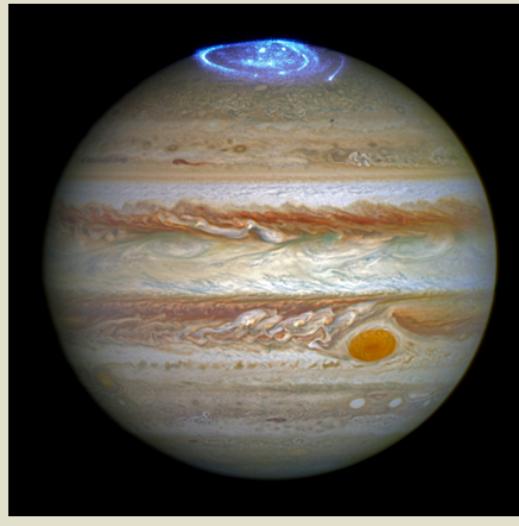
Page 4 in your text

<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



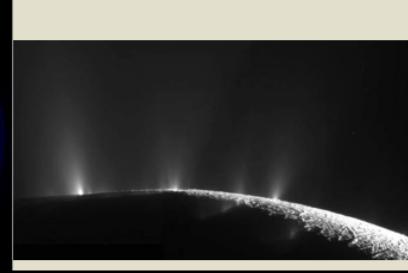
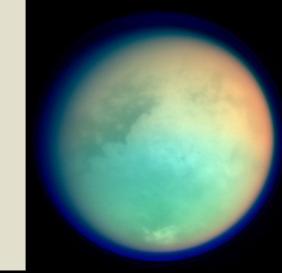
<https://arstechnica.com/science/2014/09/images-come-down-as-maven-and-mom-get-to-work-at-mars/>

<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/Ganymede_(moon))

[https://en.wikipedia.org/wiki/Io\\_\(moon\)](https://en.wikipedia.org/wiki/Io_(moon))

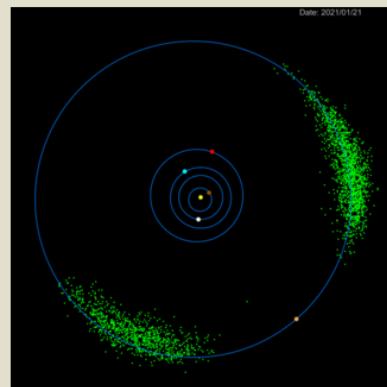
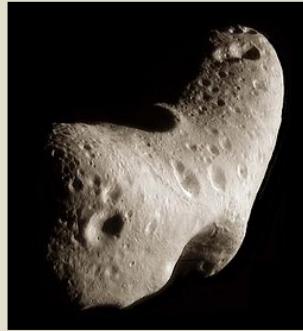
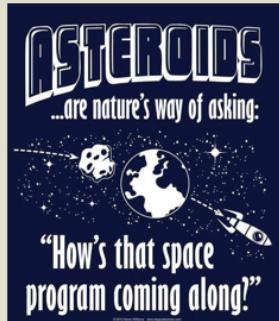
<https://www.space.com/11604-saturn-moon-titan-impacts-atmosphere.html>

<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://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

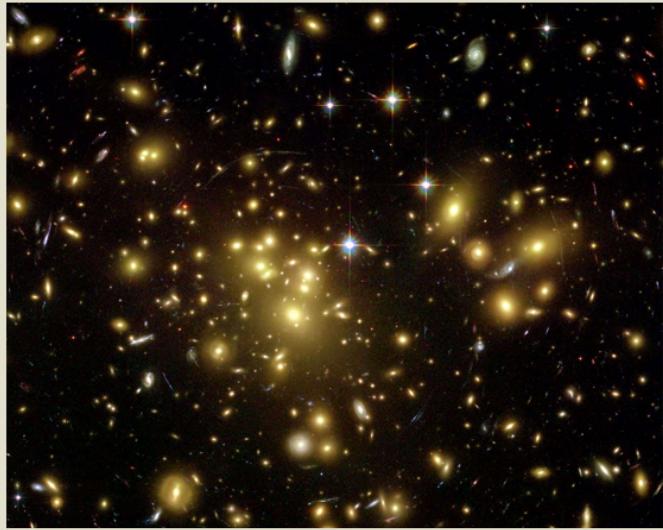


<https://www.nasa.gov/content/hubble/grand-swirls-from-nasas-hubble>

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!

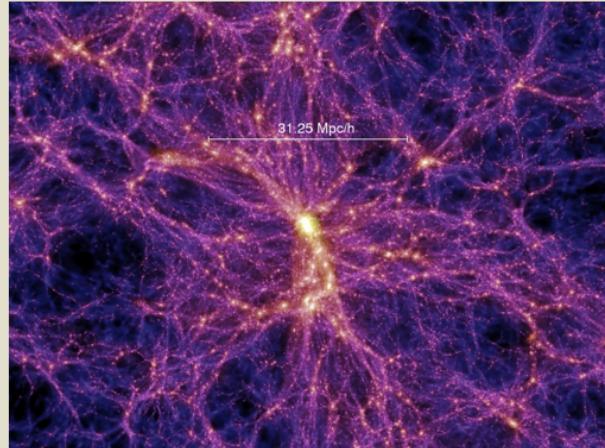
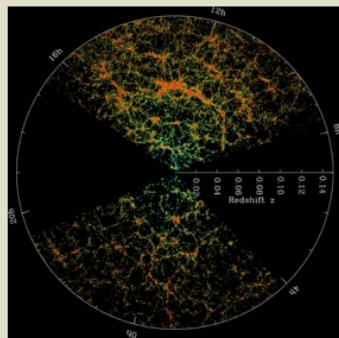


<https://www.universetoday.com/30522/galaxy-cluster/>

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](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 do we see when we look up?

<https://www.universetoday.com/74190/what-is-the-name-of-our-galaxy/>



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<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**
- **$c = 2.99 \times 10^8 \text{ m/s} = 670 \text{ million mph!}$**
- 1 LY =
  - speed × time =
  - $c \times t =$
  - $(3 \times 10^5 \text{ km/s}) \times (365.24 \text{ days}) \times (24 \text{ hours}) \times (60 \text{ minutes}) \times (60 \text{ s}) = 9.46 \text{ trillion km}$
  - Convert to AU:
    - $9.46 \times 10^{12} \text{ km} \approx 63,000 \text{ au}$

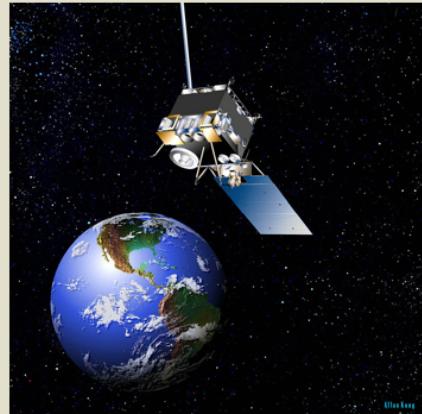


1 AU is  $1.496 \times 10^8$  km

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 16<sup>th</sup> satellite in the GOES mission series

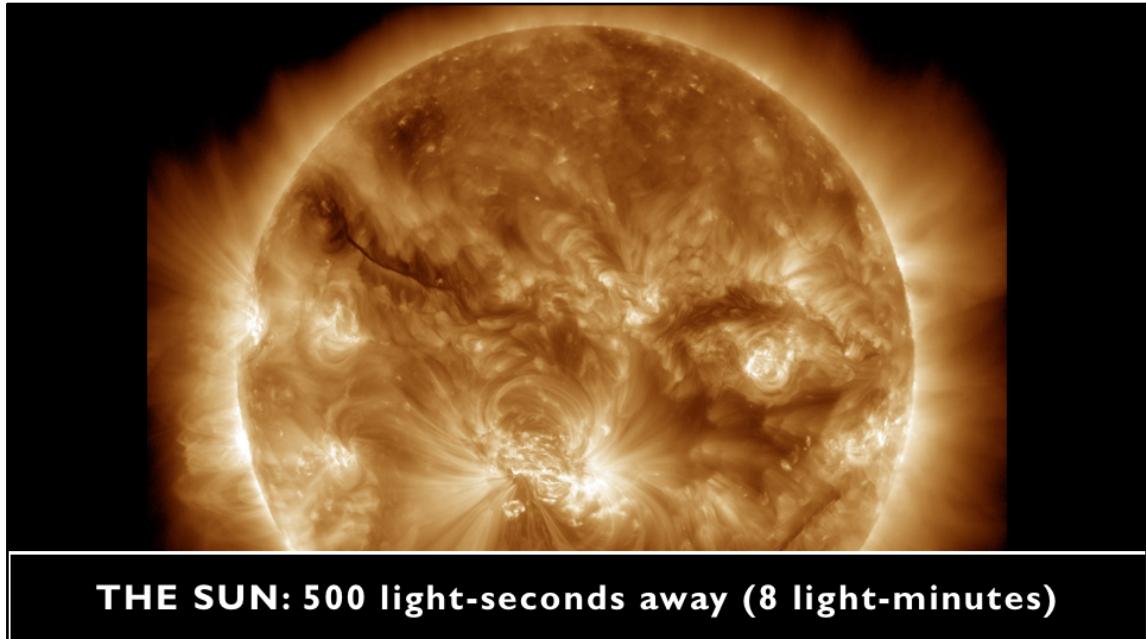


**THE EARTH: 1/10th of a light-second all the way around**

The circumference of Earth is 24,901 mi



**THE MOON: 1 light-second away**

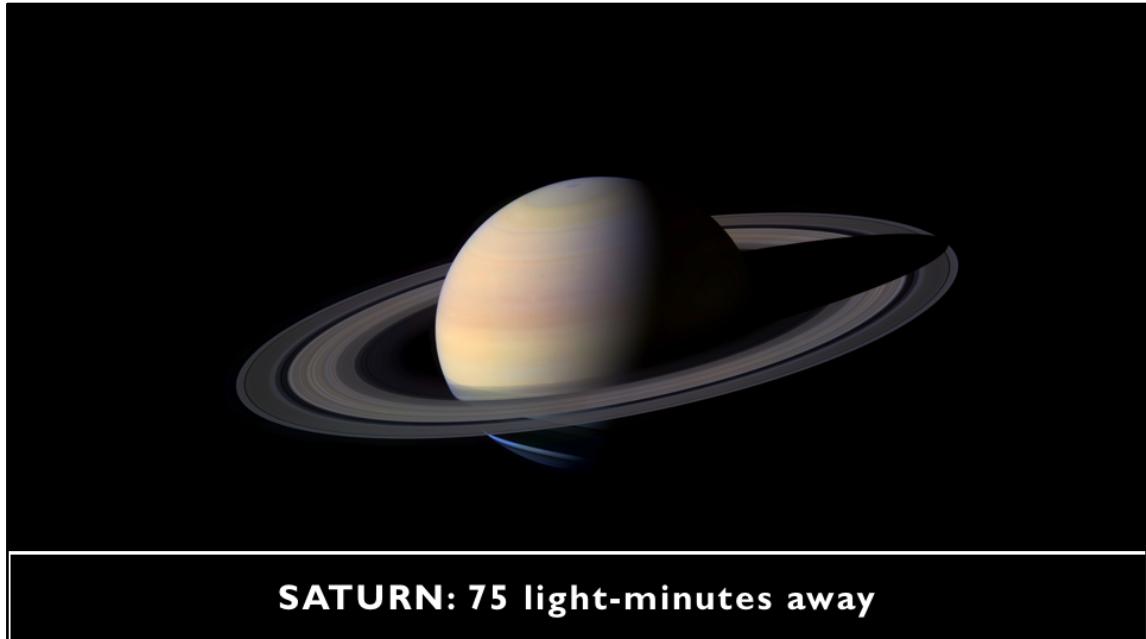


**THE SUN: 500 light-seconds away (8 light-minutes)**

Aka 1 AU!



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



**SATURN: 75 light-minutes away**

9.6 AU from the Sun (on average)



**PLUTO: 5 light-hours away**

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



24



**PROXIMA CENTAURI: 4 light-years away**

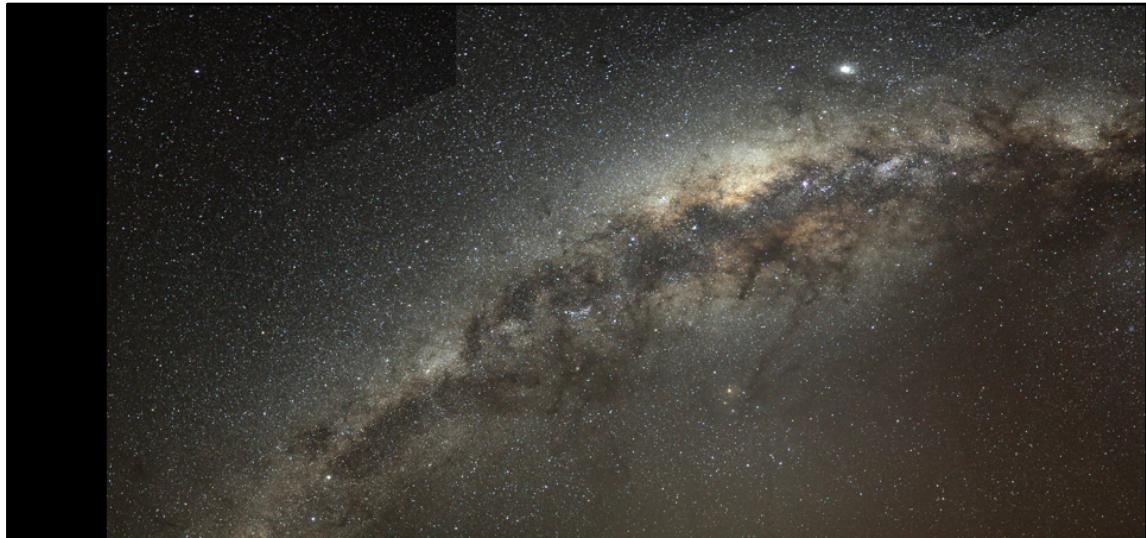
4 light years is 252,964 LY. For things this far away, it's easier to use a unit like LY than AU



**BETELGEUSE: 600 light-years away**



**THE ORION NEBULA: 1300 light-years away**



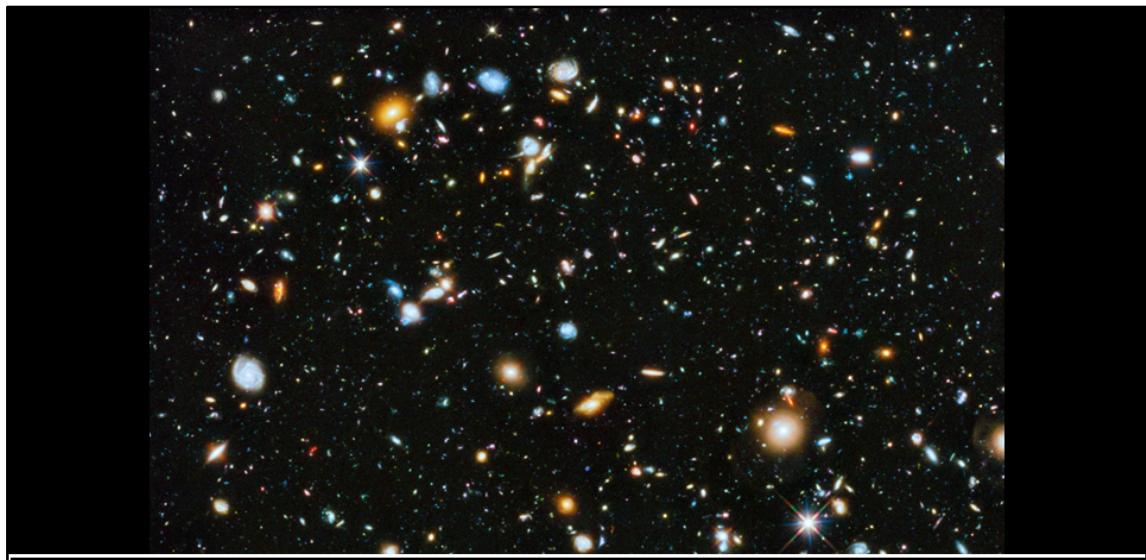
**THE MILKY WAY'S CENTER: 25,000 light-years away**



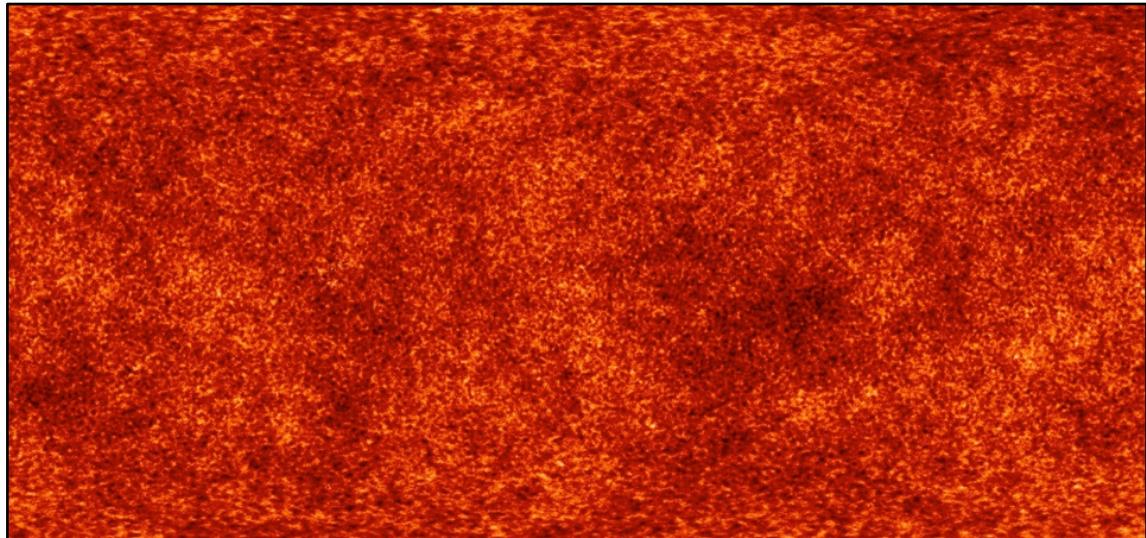
**THE ANDROMEDA GALAXY: 2,500,000 light-years away**



**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.*

## **How do we know the Earth is round?**

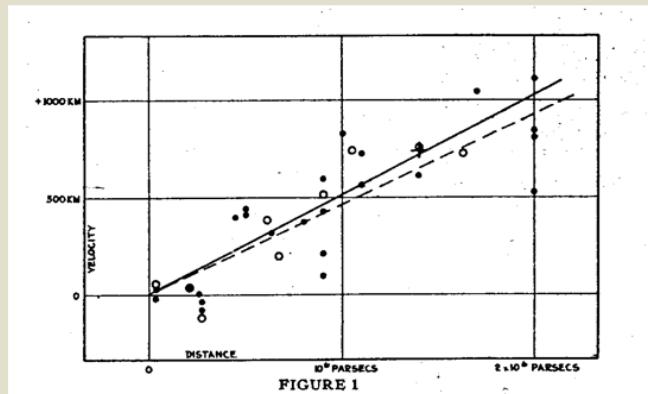
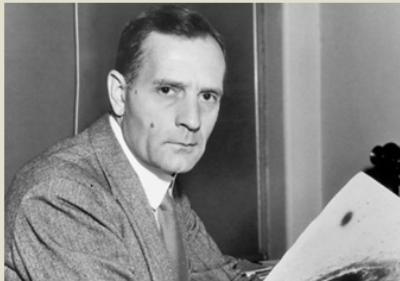
- watching a ship over the horizon
- looking at moon, seeing the shadow in eclipses
- the diffraction of light at sunset
- follow the path of a single star
- two structures at different locations on Earth, measure their shadows
- we have time zones (and can call our friends where it's dark)
- sail around the planet
- we can orbit the Earth and look at it
- stars different cross hemispheres
- double sunsets! (you can take an elevator up a tall building to see a second sunset)
- theoretical considerations! gravity pressing down symmetrically makes things round
- angles of a triangle not matching 180

You might not draw the sphere conclusion from many of these observations, if living with a Flat Earth view.

## **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



Bonus material: why do we believe the Big Bang happened?

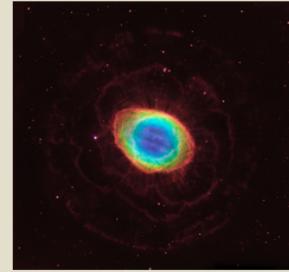
<http://astronomy.swin.edu.au/cosmos/b/big+bang>

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](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](https://www.nasa.gov/mission_pages/hubble/science/ring-nebula.html)

## 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 SO  
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=Pledt8uOxCE>

## **Cosmic Motions**

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

[https://www.youtube.com/watch?v=\\_QcgDiF1a14](https://www.youtube.com/watch?v=_QcgDiF1a14)

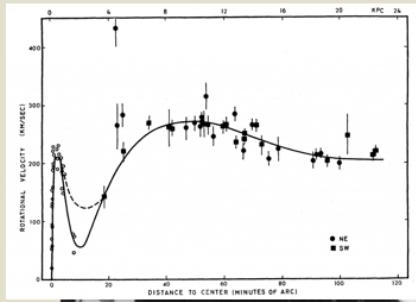
## Cosmic Motions

- 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 Zwicky
  - 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](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

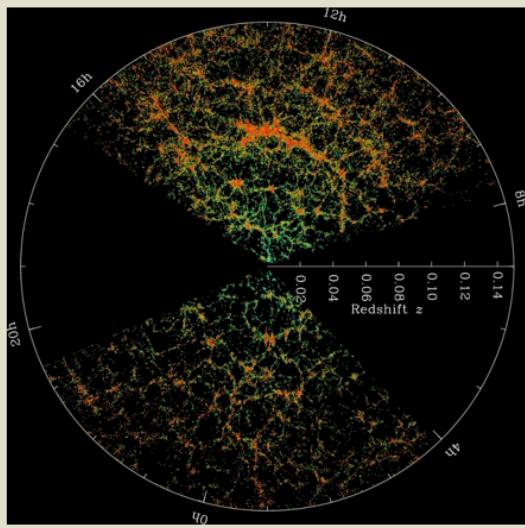
- As we sit/stand here...
  - Earth is rotating
  - We're orbiting the Sun
  - The Sun is orbiting the Milky Way
  - The Milky Way is moving in the Local Group
  - The Local Group is part of a Supercluster of galaxies



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

**The human adventure of  
astronomy**

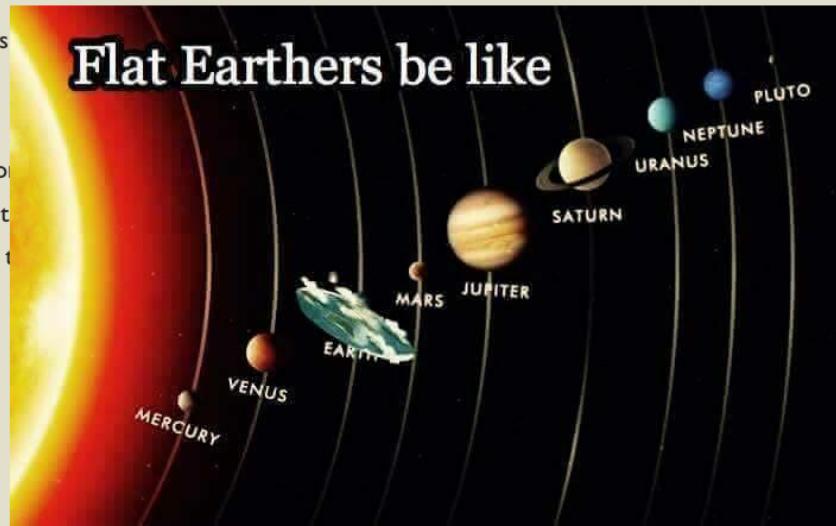
## **Practical, social, technological shifts**

- 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 by Pope John Paul II in 1992!

## Practical, social, technological shifts

- Practical applications
  - navigation
  - calendar systems
- A driver of revolution
  - social change and technology
  - our perception of time



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## Practical, social, technological shifts

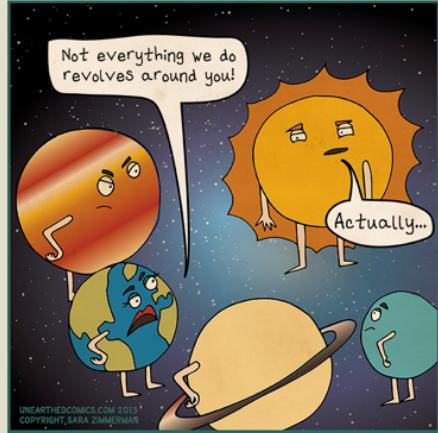
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## Practical, social, technological shifts

- 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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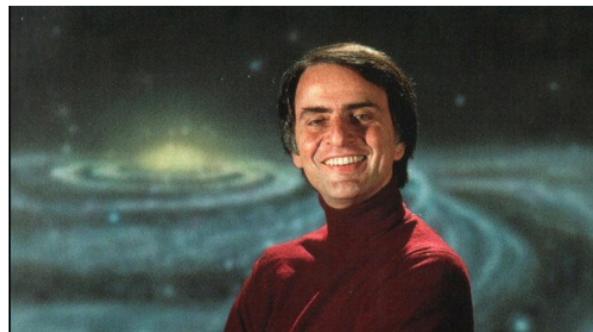
## Practical, social, technological shifts

- 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 by 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



## Pale Blue Dot

(Potentially disturbing images, viewer discretion is advised)  
<https://www.youtube.com/watch?v=sb4WhNvLRFw&frags=pl%2Cwn>

Video has some footage/images of war.