Physics 1901
Fall 2021

Lecture 1 – September. 9, 2021

Introduction

Our Place in Space

Lecture 1

- Go through Course Outline in detail

- Chapter 1: Charting the Heavens
  - 1.1: Our Place in Space

About Me
Razieh Enjilela

- Ph.D. in Physics (University of New Brunswick)
- Professional scientific research in Nuclear Magnetic Resonance and Magnetic Resonance Imaging
- Instructor at Carleton University since Fall 2020

Contact Information

- Razieh Enjilela
  - Email: Razieh.Enjilela@carleton.ca

  - Office Hours:
    - Tuesdays and Thursdays, 6:00 p.m. – 7:00 p.m. or by appointment
    - Office hours will take place using the Big Blue Button video conferencing system, which is built into Brightspace.
    - If you would like to meet at a different time, please send me an email first to ensure I will be available.

- Teaching Assistants
  - TBA

PHYS 1901 Course Overview

- 2 introductory courses on astronomy offered by Carleton:
  - **PHYS 1901: Planetary Astronomy**
    - solar system and planetary phenomena
  - **PHYS 1902: From Our Stars to the Cosmos**
    - stars, galaxies and the Universe as a whole

- These courses are aimed at general interest students who have had minimal exposure to science or mathematics
  - Explanations will rely mostly on descriptive explanations employing diagrams and pictures
  - Studying astronomy requires a basic understanding of the laws of physics, which requires some use of high school level mathematics

PHYS 1901 Course Overview

- **Introduction to Astronomy**
  - Motion of Stars and Planets in the Sky
  - History of Astronomy and the Scientific Method
  - Laws of Motion and Gravity
  - Physics of Atoms, Light and Radiation
  - Telescopes

- **The Solar System**
  - How the Solar System formed
  - Properties of the Sun and Planets, Asteroids, Comets, etc…
  - Extrasolar planets (or exoplanets): planets orbiting other stars

Course Overview

- **Textbook:**

Astronomy Today, 9th Edition by Eric Chaisson and Steve McMillan, Publisher: Pearson.

This is an eTextbook. You can purchase it online or at the University Bookstore at the University Centre.

Instructions for students that want to purchase access to the Pearson eText can be found in the below link. Please note that this link is provided for those who wants access only for 1 year ($49.99).

Get started by going to:

https://console.pearson.com/enrollment/cfpztf

Carleton University OnLine (CUOL)

- For more information:
  - **CUOL website**: www.carleton.ca/cuol
  - **CUOL Student Centre**: D299 Loeb, 613-520-4055
  - Email: cuol@carleton.ca (general information)

Lectures

- 2 lectures per week

- Each Tuesday and Thursday, the material will become available:
  - Lecture slides and Lecture recordings posted on Brightspace

- The lectures are important to learn the concepts
  - Read Textbook sections and lecture slides before each lecture
  - Watch each lecture on Brightspace
  - Lectures build on concepts from previous lectures. Don’t fall behind!

Lectures

- The first half of this course presents the basic laws of physics and astronomy
- The midterm exam will test material from Lectures 1 – 10
- The second half of this course presents an overview of our Solar System
- The final exam is cumulative.
  It will test all the material from Lectures 1 – 23

Lecture	Date	Topics	Textbook Sections
1	September 9	Course Introduction Our Place in Space	1.1
2	September 14	The Scientific Method Scientific Notation and Units in Astronomy	1.2, Appendices 1, 2
3	September 16	The Celestial Sphere, Earth's Orbital Motion	1.3 – 1.4
4	September 21	Motion of the Moon, The Measurement of Distance Ancient Astronomy	1.5 – 1.6 2.1
5	September 23	The Copernican Revolution Planetary Motion	2.2 – 2.6
6	September 28	Laws of Motion	2.7 – 2.8
7	September 30	Light and Radiation	3.1 – 3.3
8	October 5	Radiation laws, Spectroscopy	3.4 – 3.5 4.1
9	October 7	Spectroscopy	4.2 – 4.5
10	October 12	Telescopes	5.1 – 5.4
Review 1	October 14	Course Review, Part 1	1-5
11	October 19	The Solar System	5.5 – 5.8 6.1 – 6.2
12	October 21	The Solar System and its Formation	6.3 – 6.7
13	October 22	Earth	7.1 – 7.5
-	October 25-29	**Fall Break. Classes are suspended**	-
14	November 2	The moon	7.6,8.1-8.9
15	November 4	Mercury Venus	8.1 – 8.9 9.1 – 9.4
-	November 6	**Midterm Exam, 3:00 p.m. – 4:30 p.m.**	
16	November 9	Venus Mars	9.5 – 9.6 10.1 – 10.5
17	November 11	Mars Jupiter	10.6 – 10.8 11.1 – 11.2
18	November 16	Jupiter and its Moons	11.3 – 11.6
19	November 18	Saturn	12.1 – 12.5
20	November 23	Uranus and Neptune	13.1 – 13.6
21	November 25	Solar System Debris	14.1 – 14.4
22	November 30	Exoplanets	15.1 – 15.5
23	December 2	The Sun	16.1 – 16.7
Review 2	December 7	Course Review, part 2	7-16
-	December 11-23	Final examinations in fall term courses may be held.	

Student Evaluation

- The marking scheme is as follows:

Assignments (4 × 10 %)	40%
Midterm Exam	20 %
Final Exam	40 %
Course total	100 %

- In order to pass the course, your overall grade must be at least 50%.
- **In addition, you have to submit at least 2 assignments to pass the course.**

Assignments (40%)

- Assignments must be submitted no later than 11:59 p.m. Eastern Time on the above due dates.
- Late assignments are not accepted under any circumstances and I will assign a grade of zero
- I encourage collaboration with your colleagues, but that does not mean copying. The work you submit must be your own
- Submit the assignment electronically in Brightspace. **Please do not email your assignment to me or the TA.**

Assignment	Date Handed Out	Deadline
1	Thursday, September 16	Thursday, September 30
2	Thursday, October 7	Thursday, October 21
3	Thursday, October 21	Thursday, November 4
4	Thursday, November 11	Thursday, November 25

Midterm Exam (20%)

- **Saturday, November 6, 2021 at 3:00 p.m. – 4:30 p.m. Eastern Time**
- **Details:**
  - Will take place online through Brightspace
  - Open-book
  - Multiple choice questions
  - Questions will be conceptual. You won't be asked to do any math, but you should understand what the equations presented in class mean.
- More details can be find in the Brightspace

Final Exam (40%)

- Held during the Fall exam period December 11-23, 2021
  - The date and time of the exam will be announced part of the way through the term
- **Details:**
  - Will take place online through Brightspace
  - Open-book
  - Cumulative
  - Multiple choice questions
  - Questions will be conceptual. You won't be asked to do any math, but you should understand what the equations presented in class mean.
  - More details can be find in the Brightspace

Academic Accommodation

- **Requests for Academic Accommodation**
  - You may need special arrangements in case of pregnancy, religious obligations or learning disabilities.
  - See details in the full course outline on Brightspace
- Students registered with the Paul Menton Centre should discuss their learning needs with me, as soon as possible. If you don't talk to me, I can't help you properly!

Course and University Policies

- Only under the most serious of circumstances will I exempt a student from an assignment, in which case the remainder of the student's assessment will be reweighted

- Only if you have a legitimate reason for missing the midterm or final exams, a deferred exam can be scheduled for you

- **Cheating**
  - Don't do it! Any evidence of cheating will be forwarded to the Dean for evaluation. Can result in reduced overall grade or expulsion.

New minimum penalties for violations of the Carleton Policy on Academic Integrity

- First offence, first-year students (< 4.0 credits completed):
  No credit for assignment/activity in question, or a final grade reduction of one full letter grade (e.g., A- becomes B-, if reduction results in an F, so be it), whichever penalty is more severe.

- **First offence** (everyone else): F in the course

- **Second offence:** One-year suspension from program

- **Third offence:** Expulsion from the University

Failure to inform yourself of the expectations regarding academic integrity is not a valid excuse for violations of the policy.
When in doubt, ASK your instructor.

Chapter 1: Charting the Heavens

1.1: Our Place in Space

What is Astronomy?

- **Astronomy:**
  - From Greek: "*astron*" (star) and "*nomos*" (law)
  - Study of the universe
  - Based on physics, math, and chemistry
  - Uses the Scientific method:
    observation, theory, prediction, observation, . . .

- **Astronomy is NOT the same thing as Astrology**

- **Astrology:**
  - Makes predictions about individuals based on the star patterns at their birth
  - A "pseudoscience". Not based on the scientific method

The Night Sky

A typical moonless night at the Carleton Observatory:

Carleton Observatory - June 11, 2015

The Night Sky

- A typical moonless night far away from a city:

https://phys.org/news/2014-12-orion-outer-limits-milky.html

The Milky Way

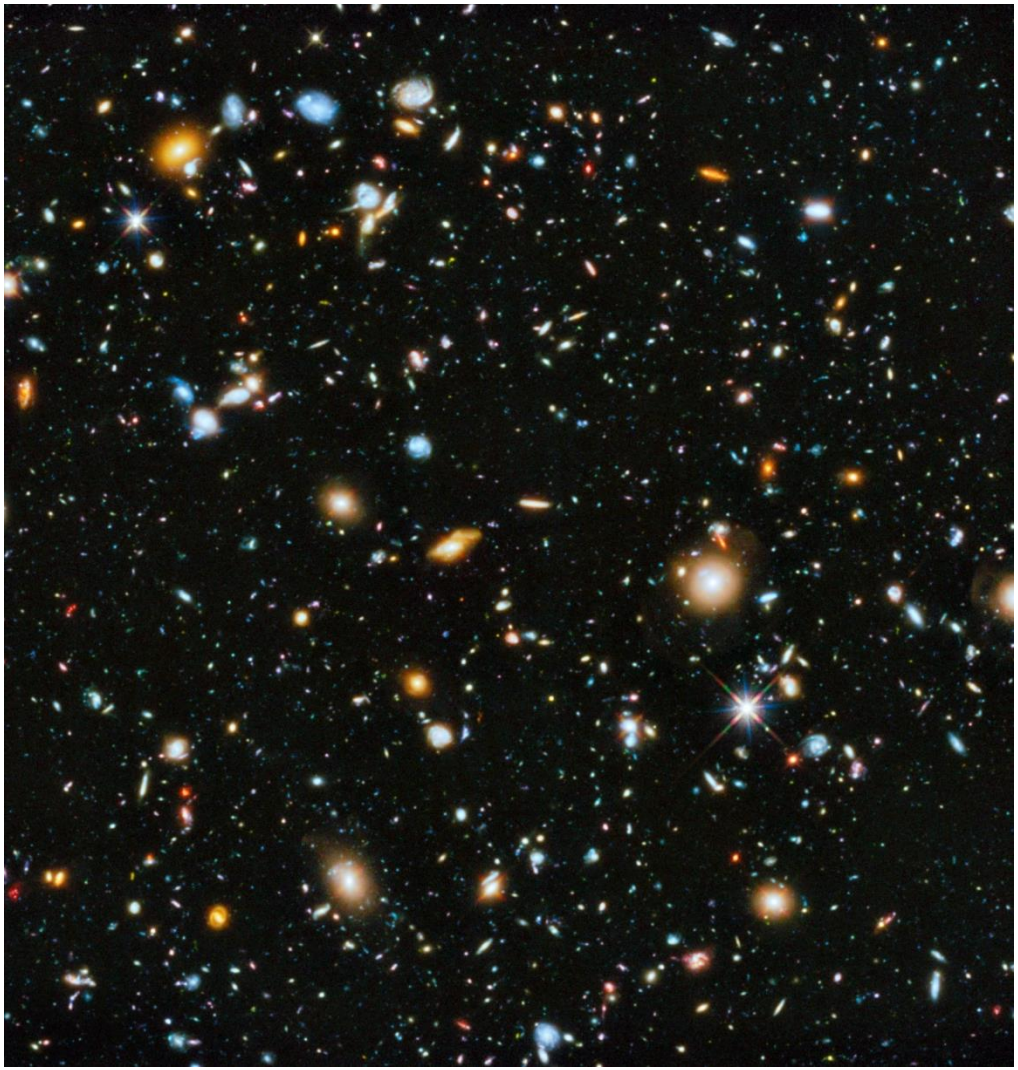
Astronomy Picture of the Day – Nov 1, 2015
https://apod.nasa.gov/apod/ap151101.html

1.1: Our Place in Space

Andromeda Galaxy
https://apod.nasa.gov/apod/ap150830

- Earth doesn't occupy a central place in the Universe
- Earth isn't special in its properties (mass, distance from Sun, etc.)
- The Sun is an average star out of billions in the Milky Way galaxy
- The Milky Way is an average spiral galaxy

- There are billions of galaxies in the observable universe



- Hubble Deep Sky Survey

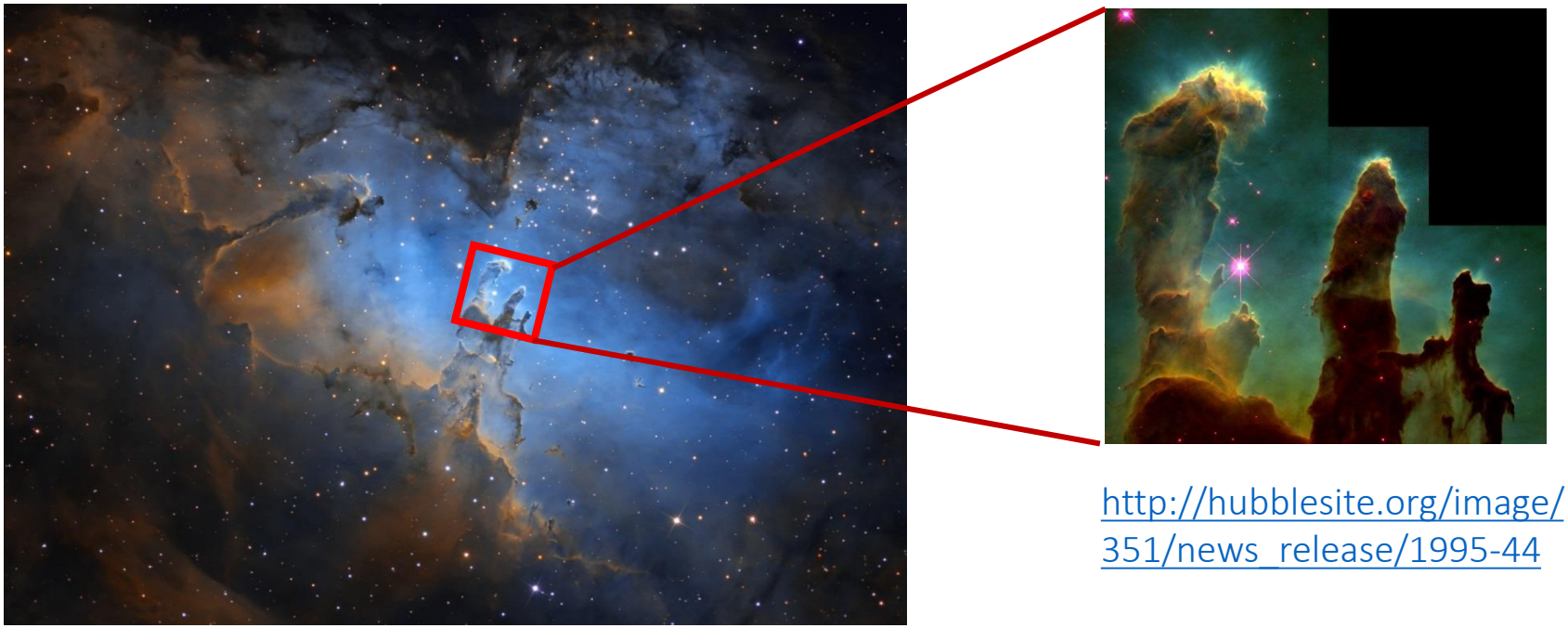
https://en.wikipedia.org/wiki/Hubble_Ultra-Deep_Field

~10,000 galaxies in a small fraction (1 / 26,000,000) of the entire sky

- The Universe is very big!

1.1: Our Place in Space

- The Universe is old, about 14 billion years
- The first stars were formed from gas clouds of the simplest chemical element: Hydrogen

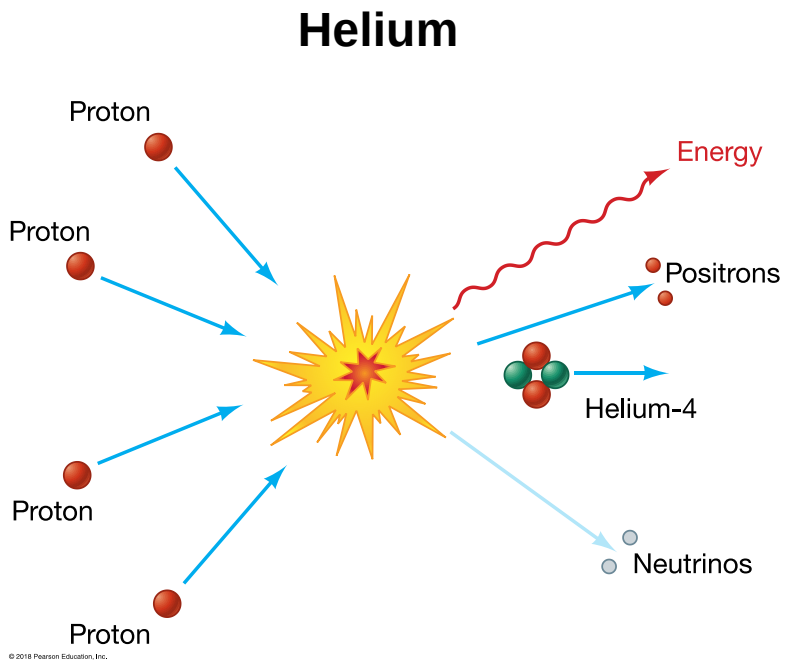


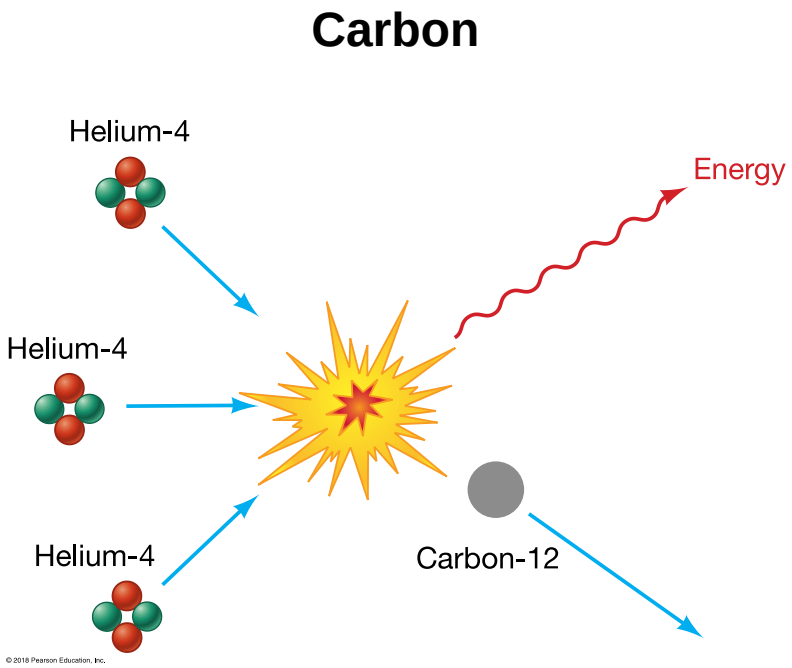
http://hubblesite.org/image/351/news_release/1995-44

The Eagle Nebula: https://apod.nasa.gov/apod/ap151015.html

1.1: Our Place in Space

- Hydrogen is converted to heavier elements in the cores of stars:



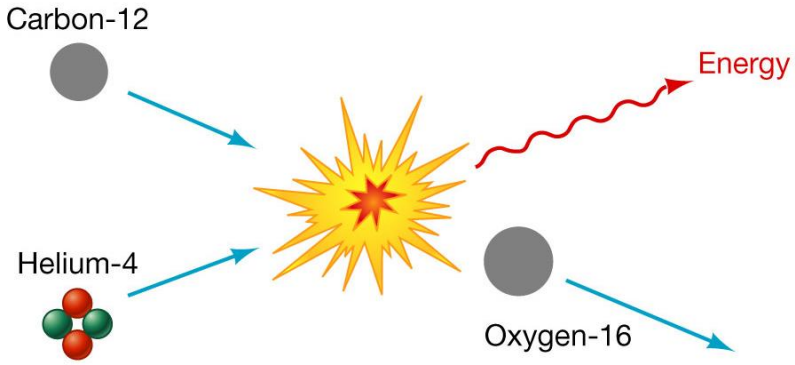


1.1: Our Place in Space

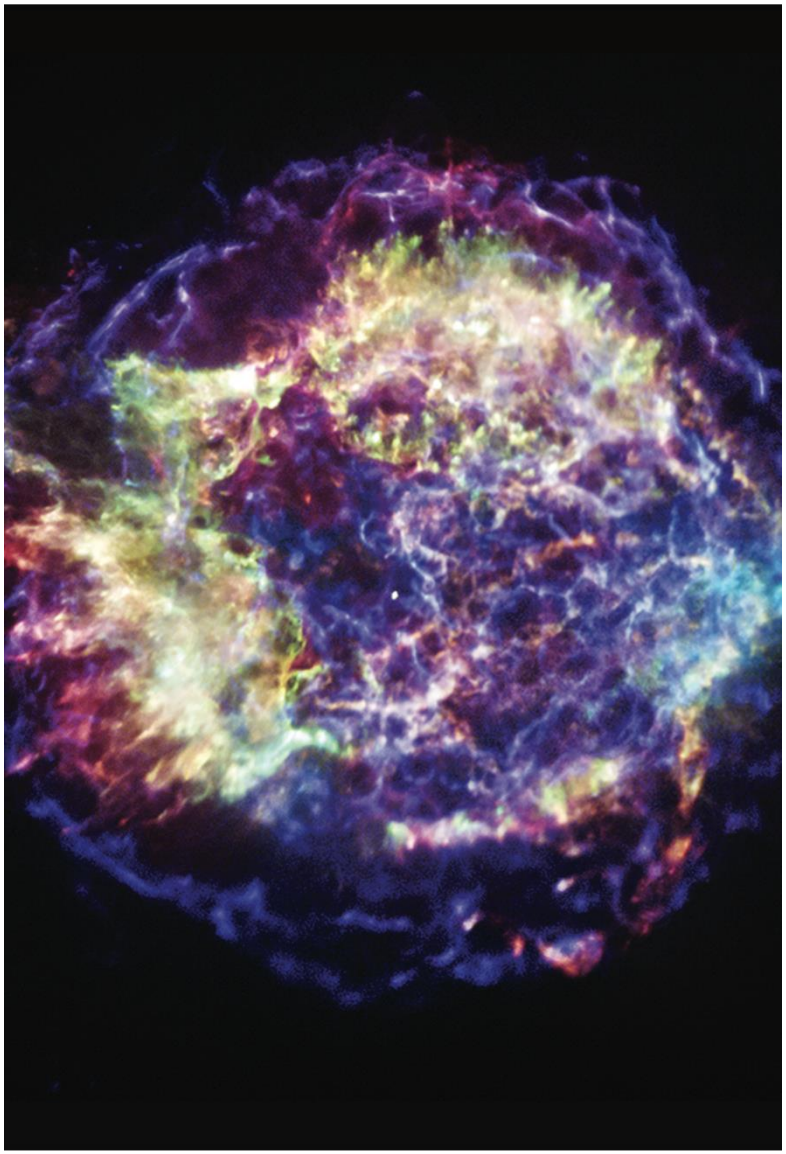
- Even heavier elements are created in the cores of stars:

Oxygen

etc…



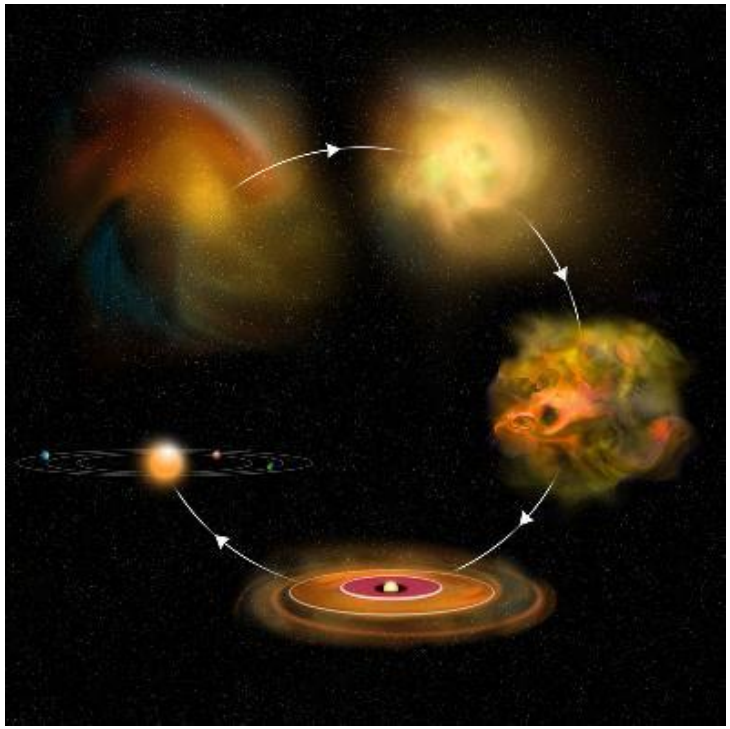
- Eventually a star uses up all its fuel. What happens next?



- If a star is heavy enough, it will die in an explosion.
- This is called a Supernova

1.1: Our Place in Space

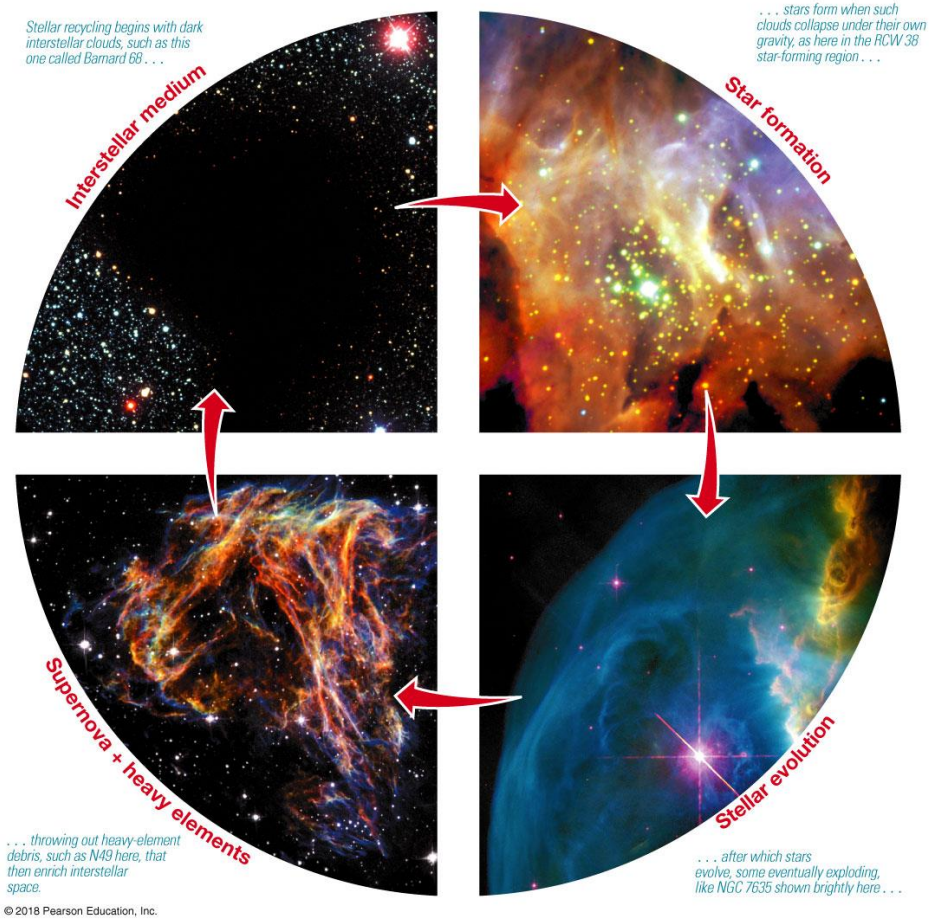
- After a supernova, all the heavy elements that were created in the star are scattered into space.
- These clouds of gas collapse to form new stars and solar systems
- Planets can form from the heavier elements



https://www.nrao.edu/pr/2012/clumpcores/

1.1: Our Place in Space

The process repeats as new generations of stars are born, age, then die



1.1: Our Place in Space

- Our Sun and its planets are about 5 billion years old
- All the atoms on Earth came from the remains of an older generation of stars
- Life on Earth would not be possible without the chemical elements created from these stars

"We are all made of stardust"

1.1: Our Place in Space

- The Universe:
  Totality of all space, time, matter and energy

- Astronomy:
  Study of the Universe

- The Universe is big, but exactly how big is it? Where do we fit in?

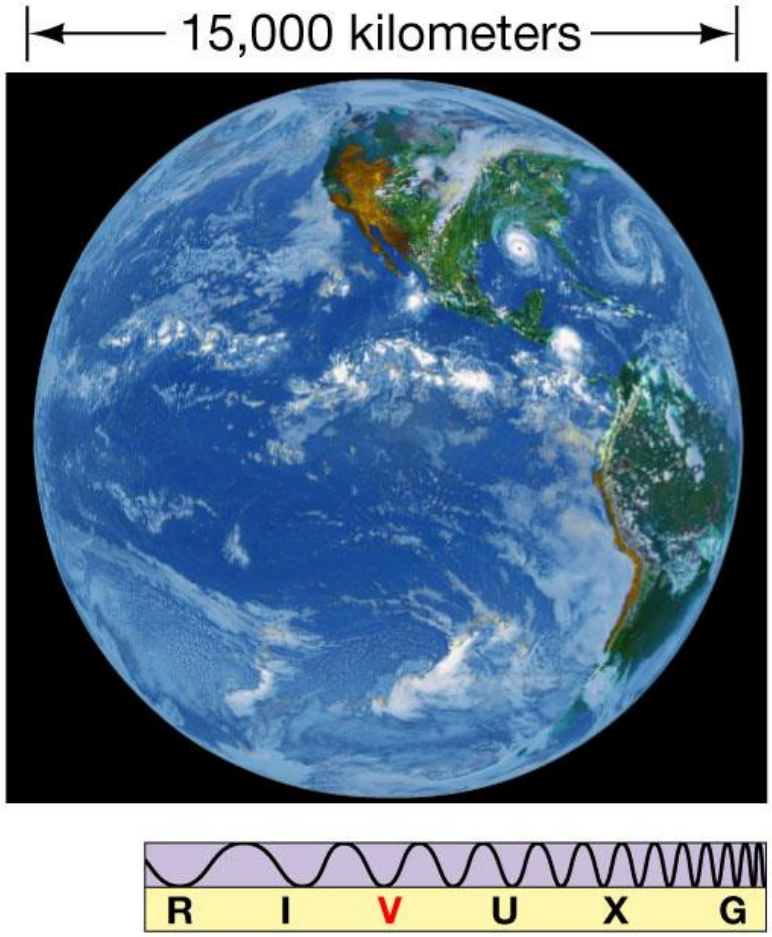
1.1: Our Place in Space

- We're familiar with distances we encounter everyday
  - Humans are about 1.5 m tall
  - This photo is about 10 m wide
  - A mountain is about 1 km
  - etc…

1.1: Our Place in Space

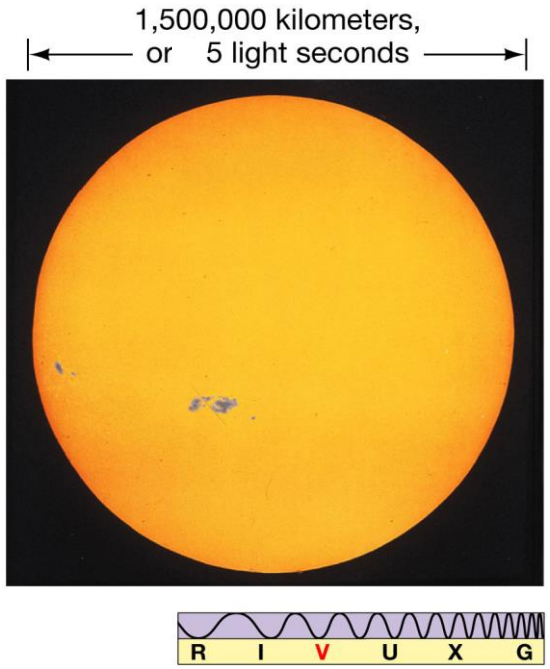
- The Earth's diameter is about 10 million times bigger than a human

- In Astronomy, distance scales are much larger



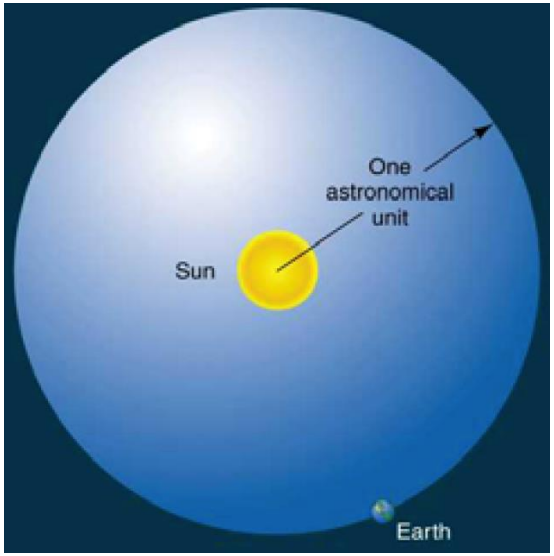
1.1: Our Place in Space

- The Sun's diameter is about 100 times bigger than Earth's
- It is an average star



- The distance from Earth to the Sun is called an **Astronomical Unit (AU)**

  1 AU ≈ 150,000,000 km



1.1: Our Place in Space

- **Galaxies** contain billions of stars like our Sun
- At these scales, it's easier to write distances in **light-years** instead of kilometers or AU
- This galaxy is about 100,000 light-years across

1.1: Our Place in Space

Galaxy Cluster

- Contains thousands of galaxies
- Millions of light-years across
- There may be billions of galaxy clusters in the Universe!

1.1: Our Place in Space

- https://www.youtube.com/watch?v=HEheh1BH34Q

- The Universe is very big! But exactly how big is it?

Light-Year

- The light-year is a unit of distance (not a unit of time)
- Light travels at a finite speed: c = 300,000 km/s
- Light takes time to get to us from distant objects
  - i.e. “Lag-time” in long distance phone calls or “live via satellite” TV interviews. Radio signals take time to travel up to satellites and to their destination
- We can define a light-second as the distance light travels in 1 second:

1 light-second = 300,000 km

1 light-second = 300,000 km

Light-Year

- Light travels fast enough to go around the Earth about 7 times in one second.
  - 1 light-second is about 7 times the Earth's circumference
- There are 60 seconds in 1 minute
  - In one minute, light travels 300,000 km × 60 = 18,000,000 km
- So, we can define a light-minute as:

1 light-minute = 18,000,000 km

- The Sun is 150,000,000 km from Earth, or about 8 light-minutes away

Light-Year

- There are:
  - 60 seconds in 1 minute
  - 60 minutes in 1 hour
  - 24 hours in 1 day
  - 365 days in 1 year

- So we can calculate how many km there are in 1 light-year:

$$1 \text{ light-year} = \underbrace{300{,}000 \text{ km}}_{1 \text{ light-second}} \times \underbrace{60}_{\text{s/min}} \times \underbrace{60}_{\text{min/h}} \times \underbrace{24}_{\text{h/day}} \times \underbrace{365}_{\text{day/y}}$$

1 light-year ≈ 10,000,000,000,000 km

- In one year, light travels about 10 trillion kilometers

Light-Year (ly)

1 ly ≈ 10,000,000,000,000 km

- An easier way to write such large numbers is using scientific notation

$$1 \text{ ly} \approx 10^{13} \text{ km}$$

- We will use Scientific Notation starting in Lecture 2 (see Appendix 1 of Chaisson & McMillan)

Light-Year

When we look at astronomical objects:

- We don’t see them as they are right now. We are seeing them as they were when the light left them. We are effectively looking back in time!

The Sun is 8 light-minutes from Earth

- We see the Sun as it was 8 minutes ago. If the Sun were to burn out or explode, we wouldn’t find out until 8 minutes later!

The next nearest star (Proxima Centauri) is 4 light-years away

- We see this star as it was 4 years ago

Galaxies are millions of light-years away

- We see galaxies as they were millions of years ago

The Universe is old… and big!

- The most distant light we can see is about 14 billion light-years away.

  14 billion ly ≈ 100,000,000,000,000,000,000,000 km = 10^{23} km

- So, the Universe is about 14 billion years old

- The oldest stars in our galaxy are about 10 billion years old

- Our Sun is about 5 billion years old

- Naturally occurring radiation in Earth rocks suggests the planets are about 4.5 billion years old

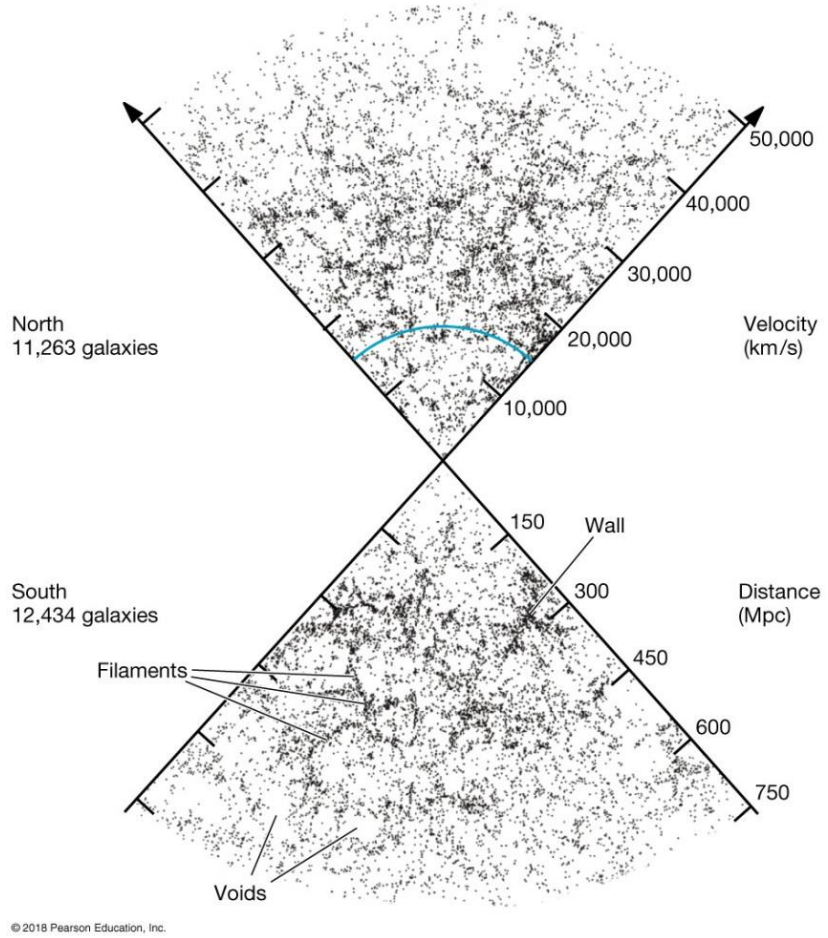
The Universe is Smooth

- The Universe is smooth with uniform ingredients

  On largest scales, the Universe looks like a smooth “dust” field (the dust is a very large collection of stars and galaxies)

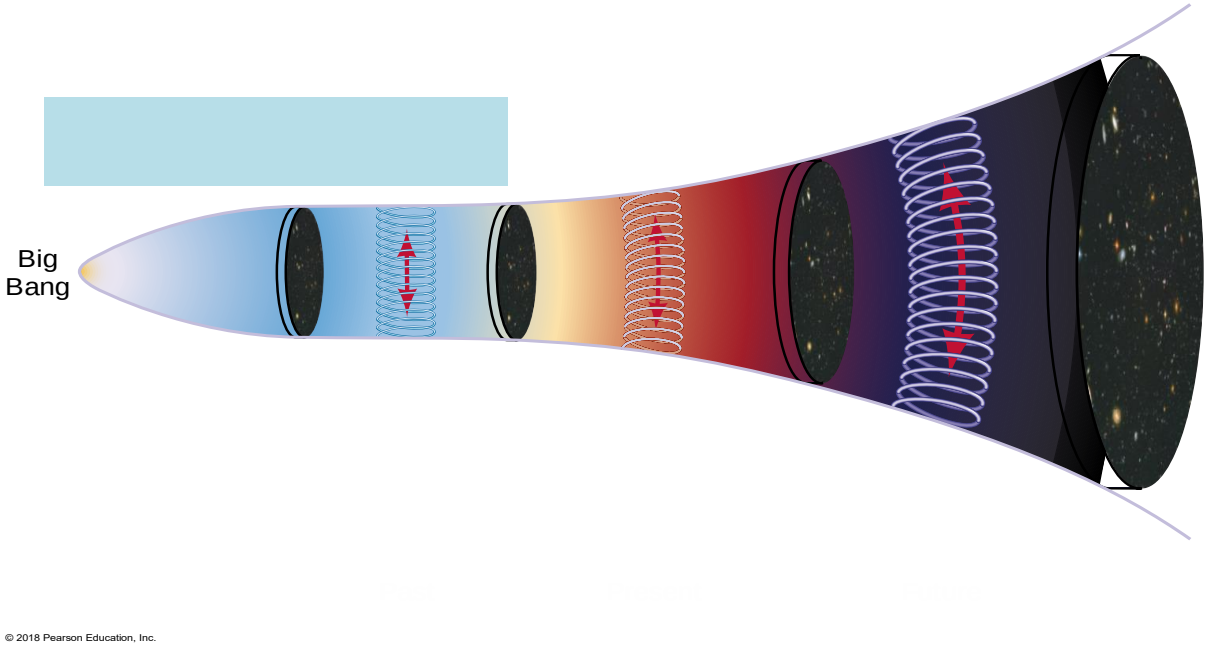
  - Cosmological Principle:
    No place in the Universe is special

- All objects in the Universe are made of the same stuff (periodic table of elements)



The Universe is Expanding

- Edwin Hubble discovered that the Universe is expanding. The distance between galaxies increases with time.



- This suggests that the Universe was created in a “Big Bang”

What we don't know about the Universe

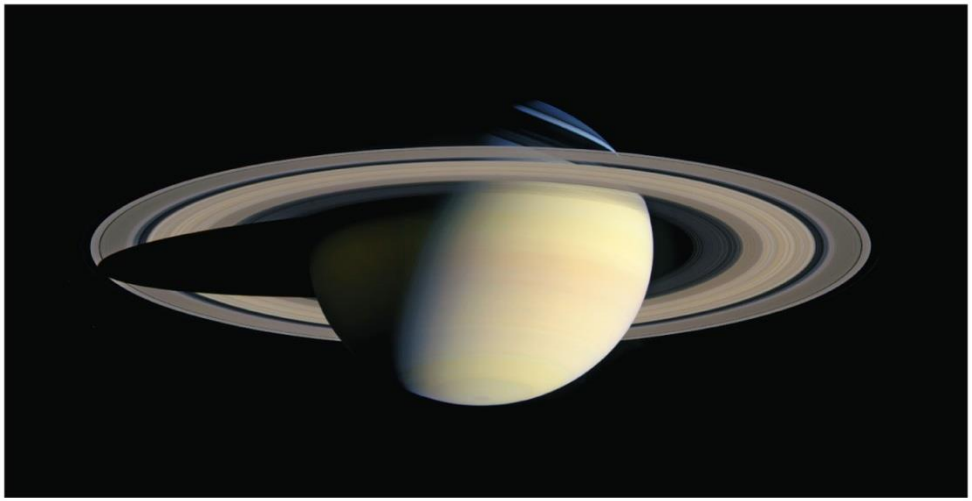
- Something is accelerating the Universe's expansion
- This could be due to Dark Matter or Dark Energy
  - Stuff that isn't in the periodic table of elements
  - Active area of research. There are many things we don't understand about the Universe.

Why Study Astronomy?

- It gives us a sense of our place in the Universe
- It helps us answer some of the most fundamental questions in nature
  - How was Earth and our Solar System formed?
  - How was the Universe formed? Will it come to an end? How old is it? How big is it? Is it getting bigger?
  - Could there be life elsewhere in the Universe?

Why Study Astronomy?

Jupiter

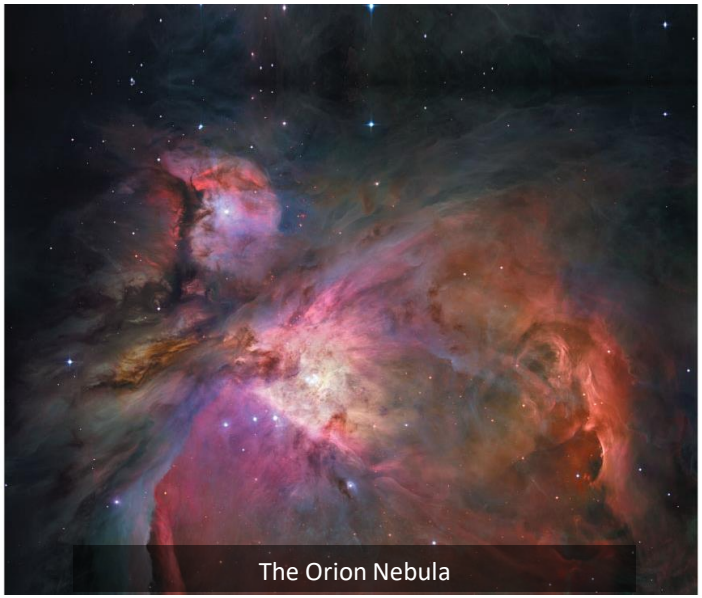


Saturn

- Astronomy is beautiful!

Why Study Astronomy?

- Astronomy is beautiful!


The Orion Nebula


The Whirlpool Galaxy - a galaxy collision

Why Study Astronomy?

- Astronomy is fun!

Next Lecture

- Number Review:
  - Appendix 1: Scientific Notation
  - Appendix 2: Astronomical Measurement
- Chapter 1:
  - 1.2: Scientific Theory and the Scientific Method