Physics 1902
From Our Star to the Cosmos
Winter 2025

Lecture 1 – January. 7, 2025

Introduction

Our Place in Space

About Me
Razieh Enjilela

- B.Sc. in Applied Physics (U. Azad)
- M.Sc. in Solid State, Physics (U. Azad)
- Ph.D. in Physics (University of New Brunswick)
- Instructor at Carleton University since Fall 2020

Contact Information

Razieh Enjilela

- Email: Razieh.Enjilela@carleton.ca

Office Hours:

- Mondays and Wednesdays, 12:30-1:30 p.m. or by appointment
- Office hours will take place using the Zoom link 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 1902 Course Overview

Two 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 1902 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

Stars

- Physical properties of the Sun and other stars
- How do stars form and evolve? What's left after they die?

Galaxies and Cosmology

- What types of galaxies are there? How do they form and evolve?
- How was the Universe created? How old is it?

Course Overview

Textbook:

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

This is an eTextbook. You can purchase it online.

Lectures

Two lectures per week

- Each Tuesdays and Thursdays, the material for that week 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
- There are 2 review lectures

Lecture	Date	Topics	Textbook Sections
1	January 7	Course Introduction, Our Place in Space	1.1
2	January 9	Scientific Notation and Units in Astronomy The Scientific Method	Appendices 1, 2, 1.2
3	January 14	The Celestial Sphere, Earth's Orbital Motion	1.3 – 1.4
4	January 16	Motion of the Moon, The Measurement of Distance, Ancient Astronomy	1.5 – 1.6
5	January 21	The Copernican Revolution, Planetary Motion	2.1 – 2.5
6	January 23	Laws of Motion	2.6 – 2.8
7	January 28	Light and Radiation	3.1 – 3.3
8	January 30	Radiation law Spectroscopy	3.4-3.5 4.1-4.2
9	February 4	Spectroscopy Telescopes	4.2-4.5 5.1-5.2
10	February 6	Telescopes	5.3-5.8
-	February 11	Course review, part 1	
11	February 13	The Sun	16.1-16.7
-	February 17-21	Winter Break. Classes are suspended.	-
12	February 25	The Stars	17.1-17.4
13	February 27	The Stars	17.5-17.8
14	March 4	The Interstellar Medium, Star Formation	18.1-18.5, 19.1-19.3
15	March 6	Star Formation Stellar Evolution of Low-Mass Stars	19.4-19.6 20.1-20.3
16	March 11	Stellar Evolution of High-Mass Stars, Stellar Explosions	20.4 – 20.6, 21.1 – 21.3
17	March 13	Stellar Explosions, Neutron Stars	21.4 – 21.5, 22.1 – 22.4
18	March 18	Relativity and Black Holes	22.5 – 22.8
19	March 20	The Milky Way Galaxy	23.1 – 23.7
20	March 25	Galaxies	24.1 – 24.5
21	March 27	Galaxies and Dark Matter	25.1 – 25.5
22	April 1	Cosmology	26.1 – 26.7
23	April 3	The Early Universe	27.1 – 27.6
-	April 8	Course review, part 2	18-27

Student Evaluation

The marking scheme is as follows:

Assignments (2× 15 %)	30 %
Midterm Exam	15 %
Final Exam	25 %
Class activities	35%
Course Total	100 %

- In order to pass the course, your overall grade must be at least 50%.
- **In addition, you must submit at least 3 course requirements (out of 2 assignments and 2 class activities) to pass the course**. Please note that if you choose to submit only three assignments, the grade for the missed assignment will not be redistributed among the others, and you will lose the marks for the one not submitted.

Assignments (65%)

- Assignments must be submitted no later than 11:59 p.m. Eastern Time on the above due dates.
- Late submissions will be graded with a 10% per day penalty up to a maximum of 50%.
- 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 at all.**

COMPONENT	GRADE VALUE	DATE
ASSIGNMENT 1	15 %	January 14-January 28
CLASS ACTIVITY 1	20 %	January 31-February 16
ASSIGNMENT 2	15 %	February 16- March 5
CLASS ACTIVITY 2	10 %	March 7-March 21

Midterm Exam (15%)

Friday, February 28, 2025 at 6:00 p.m. – 7:30 p.m. Eastern Time

Details:

- Will take place online through Brightspace
- Open-book
- 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 found in the Brightspace

Final Exam (25%)

Held during the Winter exam period April 11-26, 2025. 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 will be announced at a later date

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 I will 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.

Lecture 1

- Go through Course Outline in detail

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

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

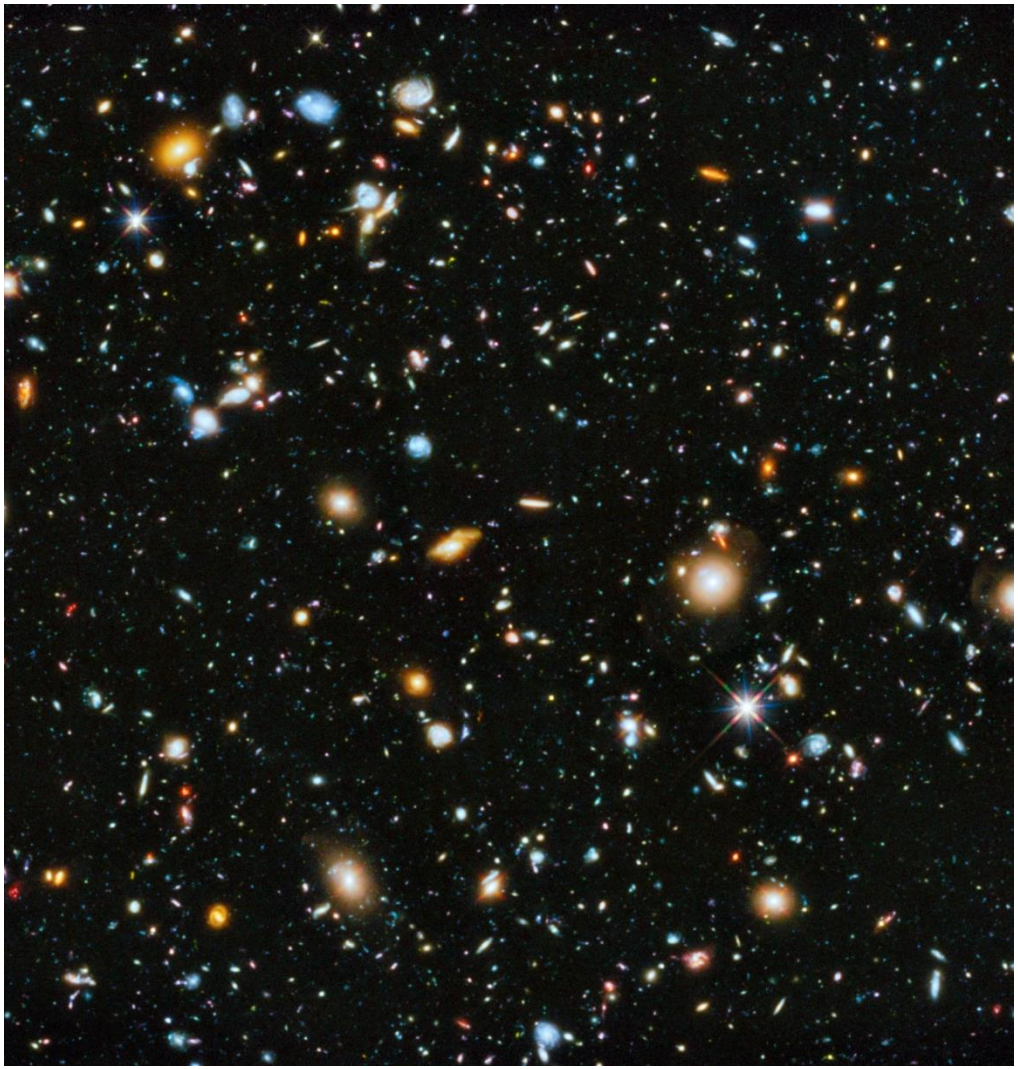
Astronomy Picture of the Day – Nov 1, 2015
https://apod.nasa.gov/apod/ap151101.html

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

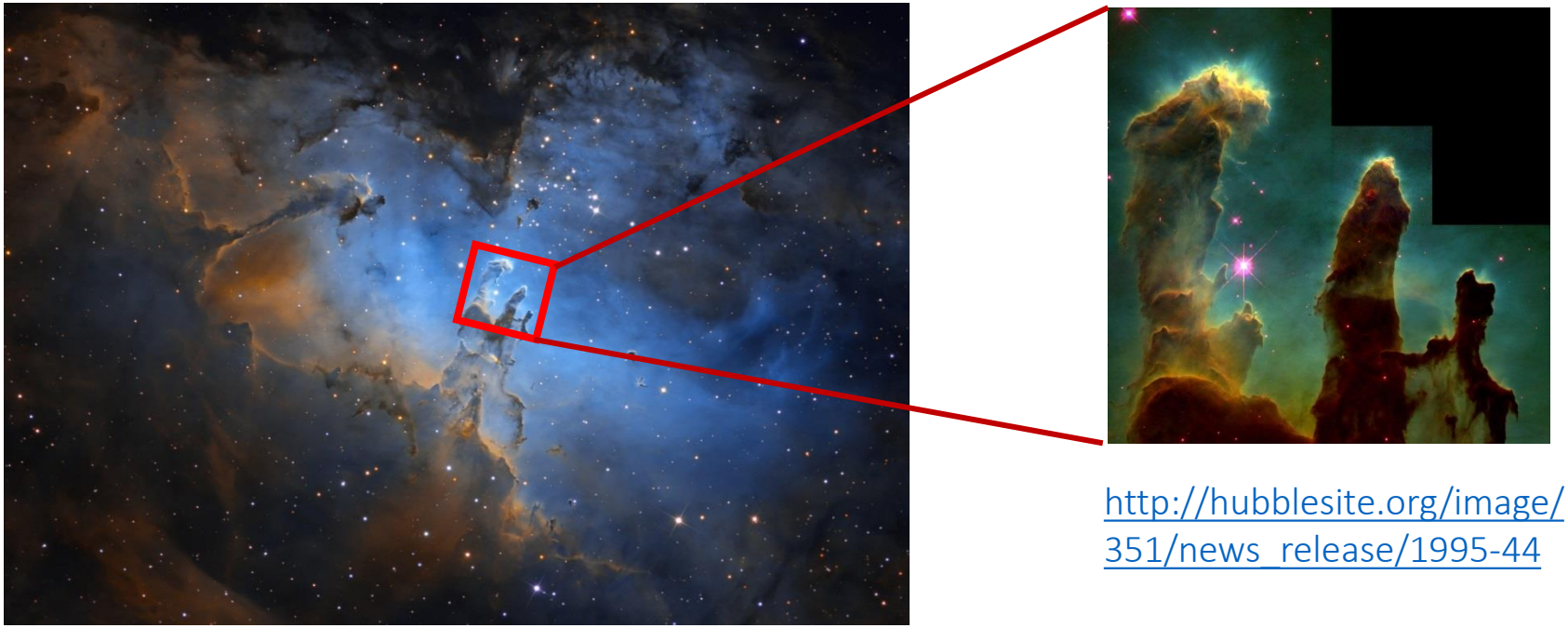
https://en.wikipedia.org/wiki/Hubble_Ultra-Deep_Field

~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

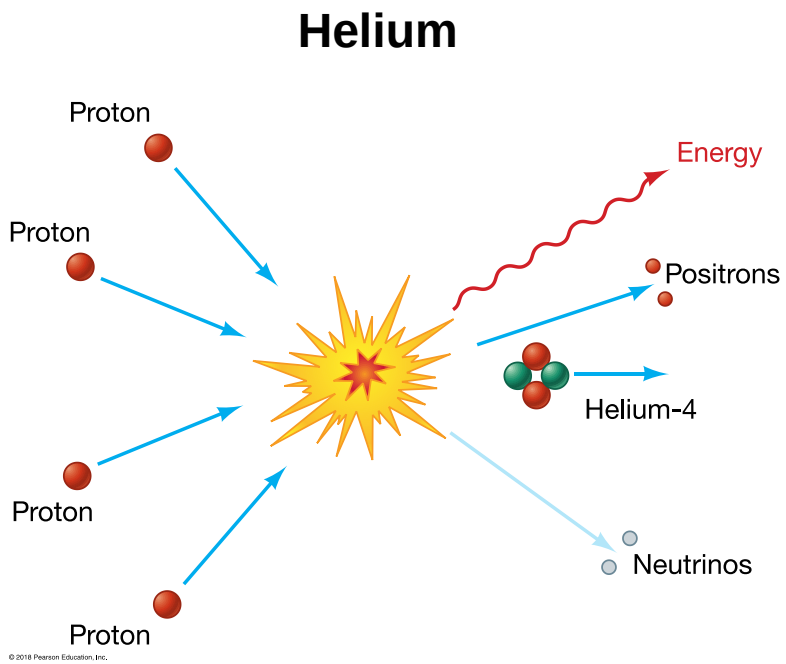


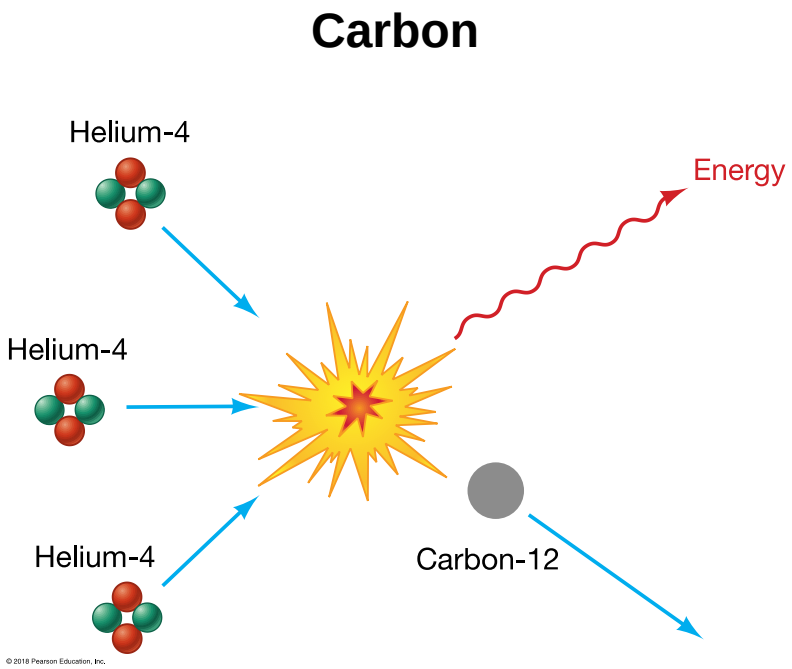
http://hubblesite.org/image/351/news_release/1995-44

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:



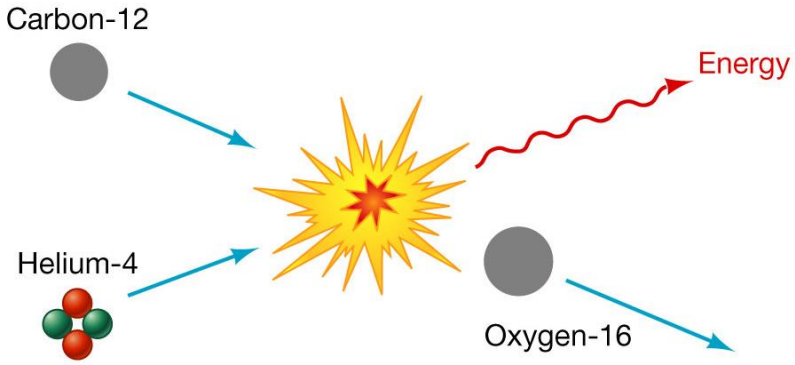


1.1: Our Place in Space

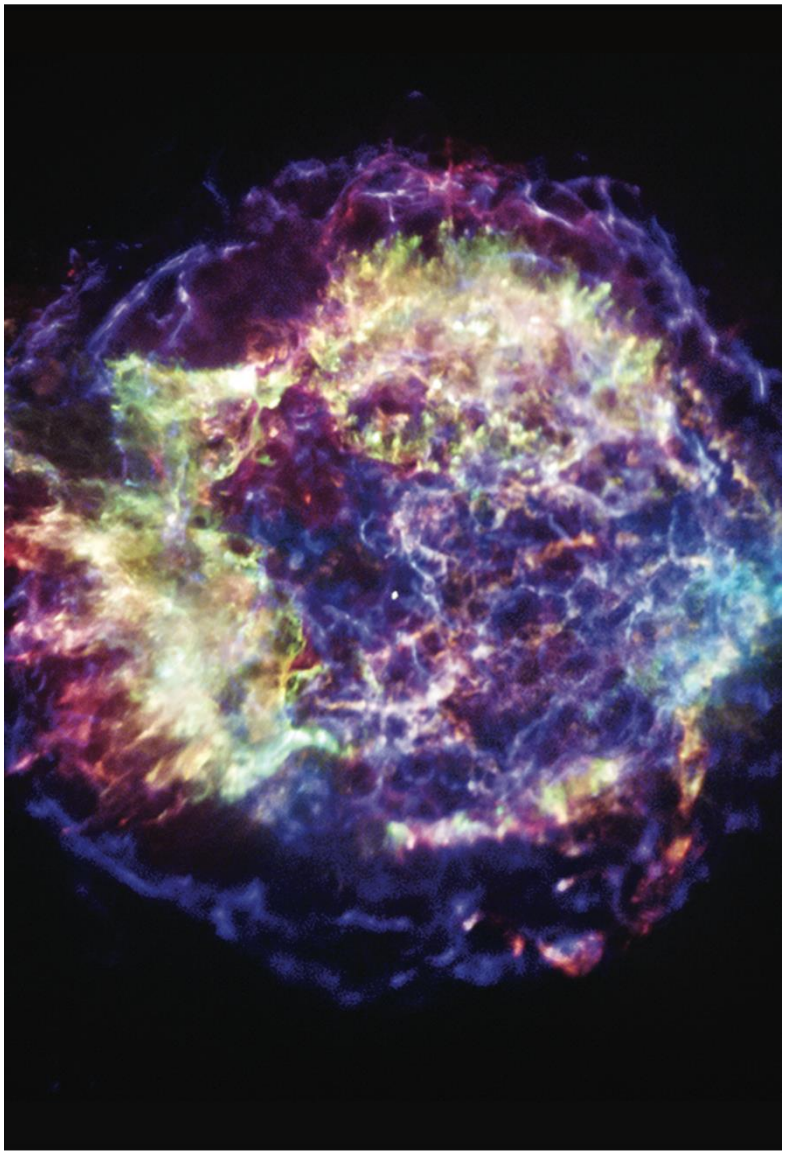
- Even heavier elements are created in the cores of stars:

Oxygen

etc…



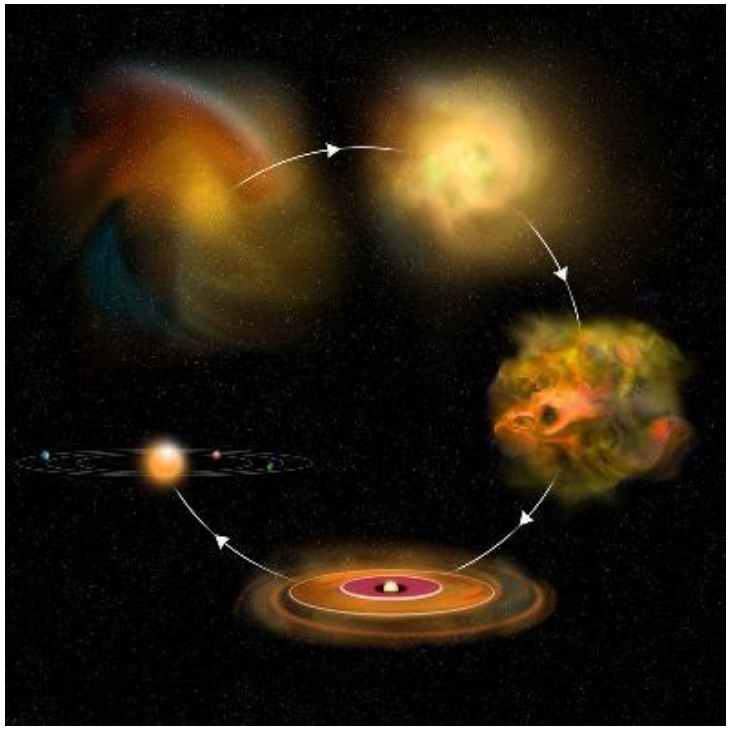
- Eventually a star uses up all its fuel. What happens next?



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

1.1: Our Place in Space

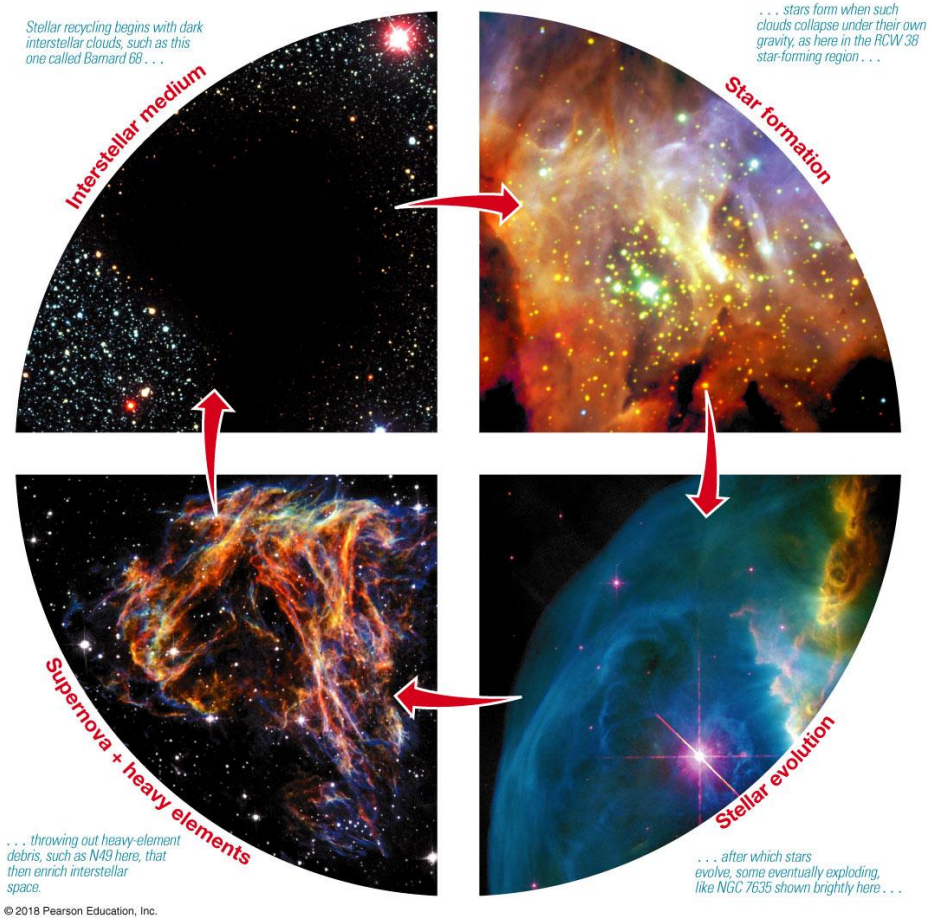
- After a supernova, all the heavy elements that were created in the star are scattered into space.
- These clouds of gas collapse to form new stars and solar systems
- Planets can form from the heavier elements



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

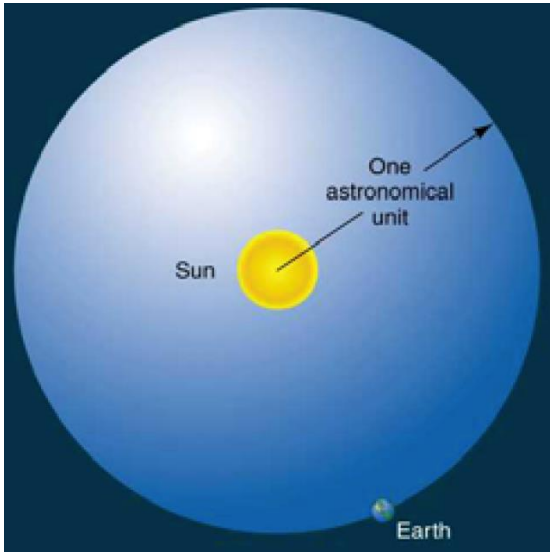
- In Astronomy, distance scales are much larger

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

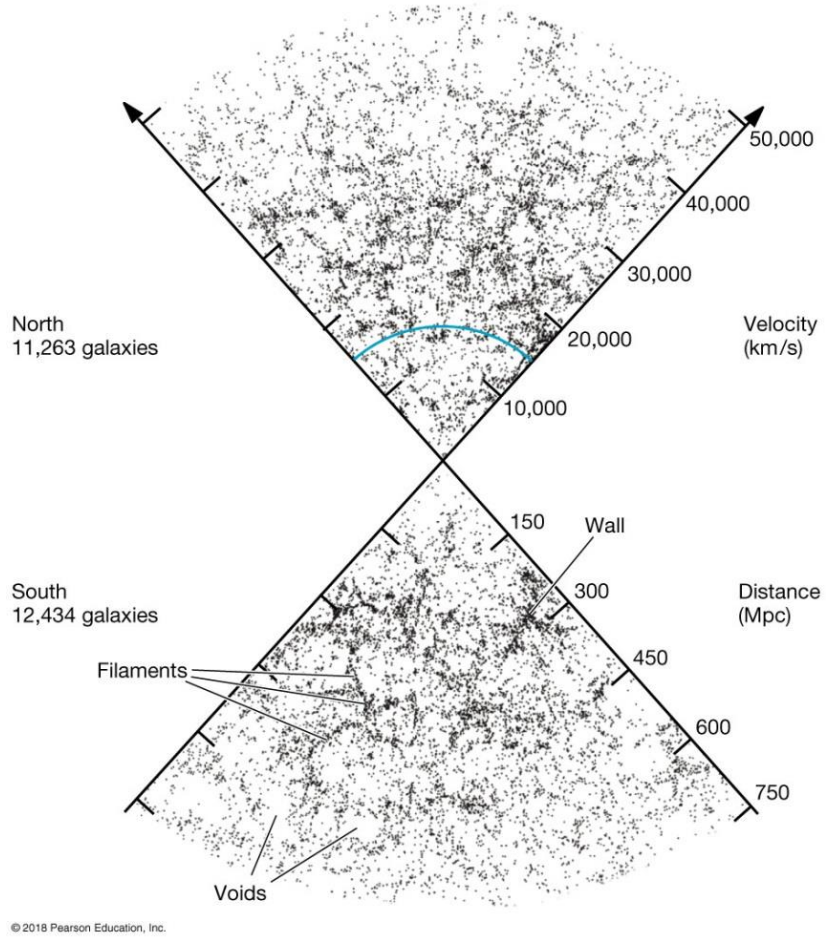
The Universe is Smooth

- 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)

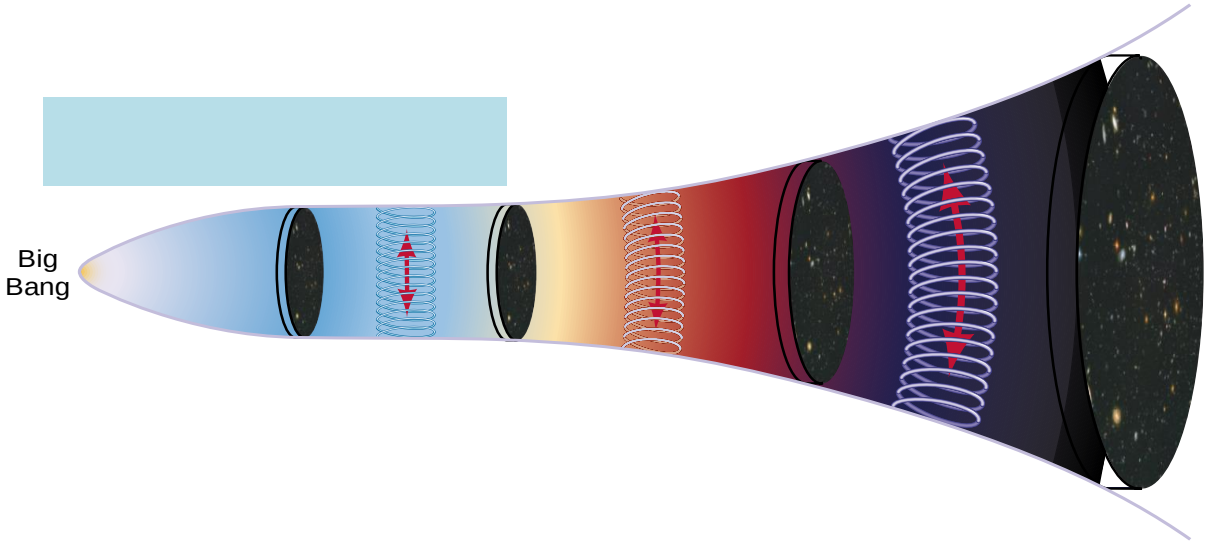
  - Cosmological Principle:
    No place in the Universe is special

- 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

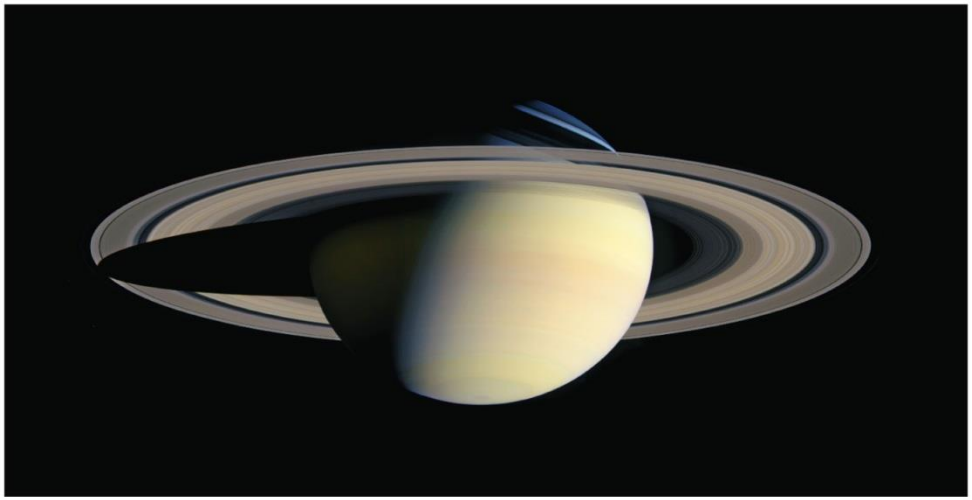
- Something is accelerating the Universe's expansion
- This could be due to Dark Matter or Dark Energy
  - Stuff that isn't in the periodic table of elements
  - Active area of research. There are many things we don't understand about the Universe.

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

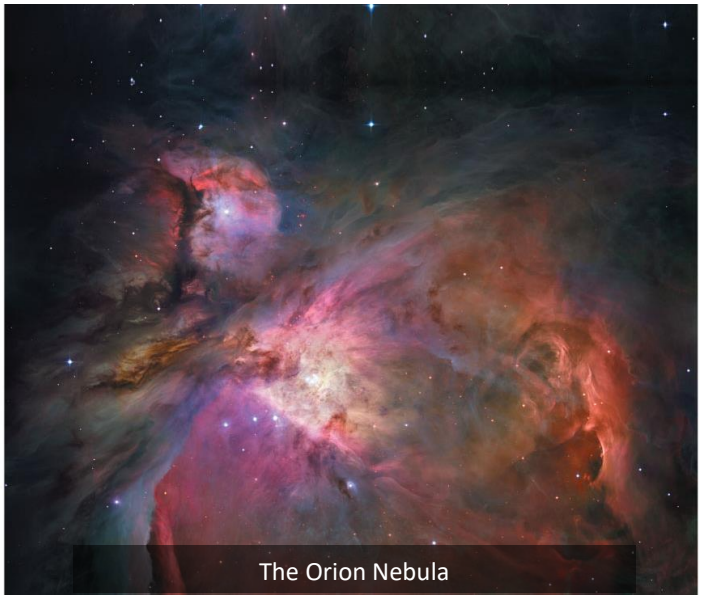


Saturn

- Astronomy is beautiful!

Why Study Astronomy?

- Astronomy is beautiful!

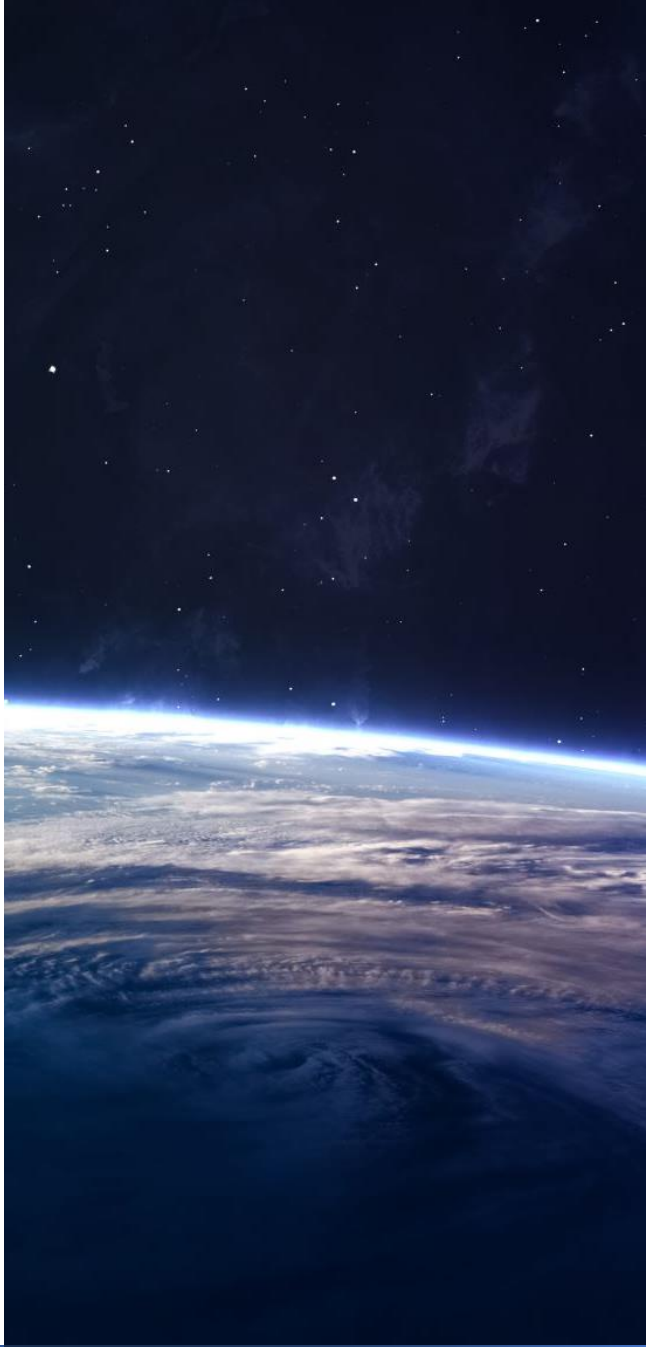


The Orion Nebula

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