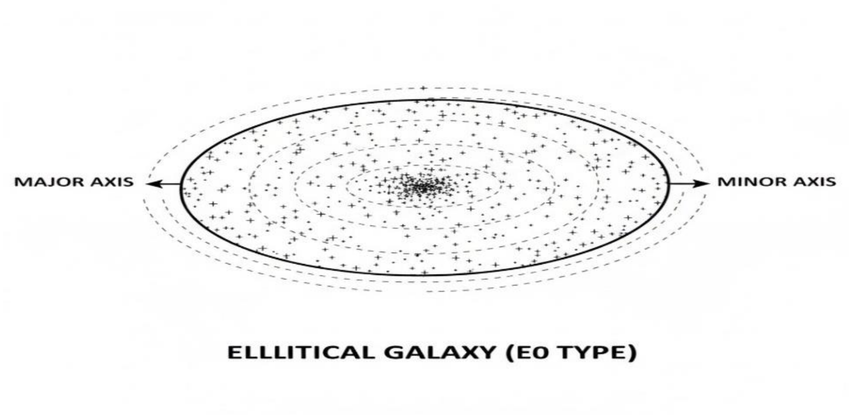
<u>**Chapter 1: The Universe**</u>

1. **Galaxy**

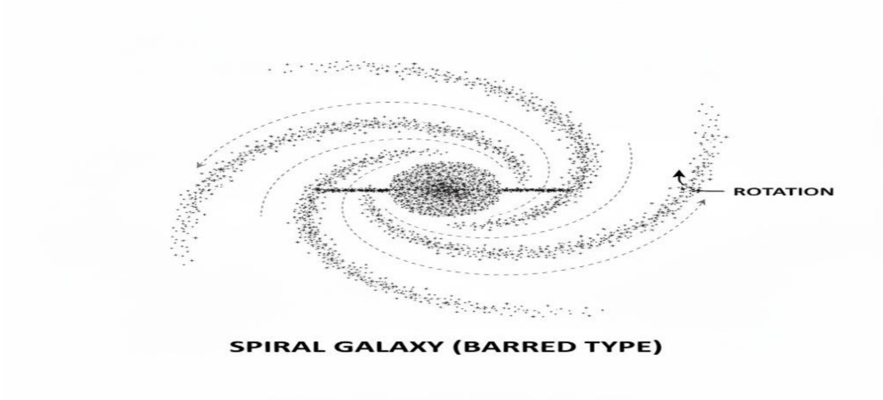
- A galaxy is a gravitationally bound system comprising of blackholes, stars, nebulae, stellar remnants, planets, dwarf planets, small solar system bodies, and satellites.
- It is the fundamental unit of the universe
- Collection of galaxies is called cluster and arm of galaxies are called galactic arms.
- The basic requirement for any galaxy is "gravity" and gravity is produced/engendered by the blackhole.
- Black hole are usually at the center of the galaxy
- Astronomers estimate that there are 100 to 200 billion galaxies in the observable universe
- They range in size from dwarf to giants with one hundred trillion stars
- They're so big that sometimes they are called Island universes
- They are categorized according to their visual morphology
- American astronomer **Edwin Hubble** classified galaxies into four main types in 1926.

i. **Elliptical Galaxies**



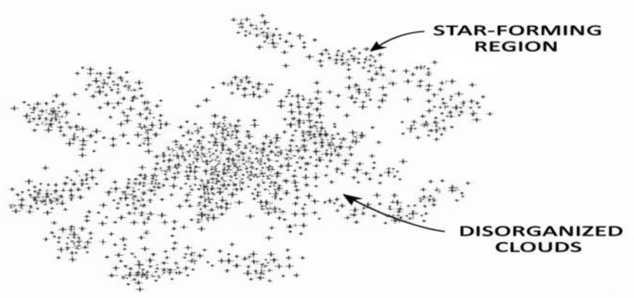
- Most abundant type of galaxies found in the universe
- They have an elliptical or spherical shape / they have an elliptical profile / they bear the rounded shape of an ellipse
- They have smooth appearance
- Because of their age and dim qualities, they are frequently outshone by the younger, brighter collection of stars.
- They have older stars and have very little gas/dust
- Star formation is low.
- They lack swirling arms
- M87 is an example of this type of galaxy.

ii. **Spiral Galaxies**



- They get their name from the shape of their disks.
- They are flat, rotating spiral structures.
- It has a center bulge and spiral arms
- Stars, gas, and dust are gathered in spiral arms that spread outward from the galaxy's center.
- There is active star formation going on in the arms
- They are divided into three main types depending on how tightly wound their arms are
  - **Sa:** these galaxies have very tightly wound arms around a larger central nucleus
  - **Sc:** these galaxies have loosely wound arms around a smaller nucleus
  - **Sb:** these galaxies have moderately wound arms around an average sized nucleus
- These galaxies have a lot of gas, dust, and newly forming stars
- Since there's lots of hot, young stars, they are often among the brightest galaxies in the universe.
- About 20% of the galaxies are spirals.
- Milky Way and Andromeda are the examples.

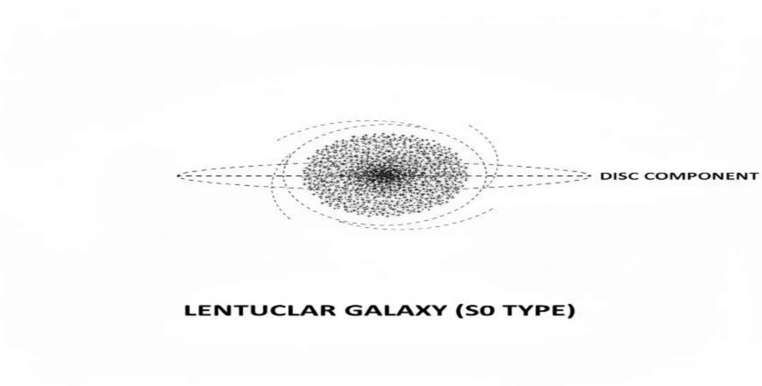
iii. Irregular Galaxies



IRREGULAR GALAXY (Irr TYPE)

- These galaxies have no particular shape
- These are among the smallest galaxies and are full of gas and dust
- They have a lot of star formation going on with them
- These are very bright galaxies
- About 20% of the galaxies are irregular
- Large and Small Magellanic clouds are the examples.

iv. Lenticular Galaxies



- These are intermediate between elliptical and spiral
- They're like spiral galaxies but no spiral arms.
- They have moderate star formation going on
- NGC 4886 is an example.

➢ Certain key points for milky way
- The name of our galaxy is Milky Way and it's a spiral galaxy
- It contains 200 to 400 billion stars
- It has spiral arms rich in gas, dust, and young stars
- Part of the local group of galaxies.
- Has a central blackhole called Sagittarius A*
- The sun is not the largest star of the milky way.
- Our Solar System is located in the Orion Arm, about 27,000 light years from the center.
- Formed about 13.7 billion years ago
- Is about 100,000 light years in diameter
- Sun takes approximately 225 to 250 million terrestrial years to complete one orbit around the center of the Milky Way Galaxy, and this period is indeed called a galactic year or cosmic year.
- Nearest galaxy to Milky Way is Andromeda

➢ Certain key points for Andromeda
- Closest major galaxy to the Milky Way
- A spiral galaxy, slightly larger than the Milky Way
- Has a bright, dense central bulge
- Contains a supermassive blackhole in its center
- Most massive member of the local group
- Contains over 1 trillion stars
- Its diameter is about 220,000 light years
- Surrounded by many dwarf galaxies like M32, M110
- Is moving towards the Milky Way at about 110 km/sec

➢ The future of Milky Way and Andromeda
- Andromeda is moving towards the Milky Way at about 110 km/sec
- Both are expected to collide and begin merging in about 4-5 billion years
- Gravity will distort both galaxies, creating massive tidal tails
- Their central black holes will merge into one larger black hole
- Two galaxies will settle into a new larger galaxy
- Resulting galaxy will be an elliptical or lenticular type galaxy.
- Scientists call this future merged galaxy **"Milkdromeda" or "Milkomeda"**

2. Solar System

- A gravitationally bound system of the Sun and all objects orbiting it, including planets, dwarf planets, moon, asteroids, comets, and meteoroids.
- Formed about 4.6 billion years ago from a rotating cloud of gas and dust called the solar nebula. Under gravity, cloud collapsed and the material formed the Sun and a disc of mater in which the planets were born.
- The word "Solar System" refers to the Sun and all the objects that travel around it.
- Distance between our Solar System & the blackhole is 26,000 to 27,200 light years.
- We have 8 Planets in the solar system, first four are **terrestrial planets** and **the rest are jovial planets**
- An easy way to remember 8 planets is **"my very educated mother just served us noodles"**

i. Mercury

- Nearest planet to the Sun
- It has no moon
- The fastest revolving planet
- Has no atmosphere
- Smallest Planet
- Made of dense rocky materials, therefore, has a very high density.
- Has the fastest orbit of 88 days. (mercury revolves around the sun in 88 days)
- 58 million km away from the Sun.
- Distance from the sun is 0.3 AU

ii. Venus

- 2^{nd} planet of the solar system
- Also called the morning star and twin of the earth
- Slowest revolving planet
- Hottest and brightest planet
- Has very thick, rapidly, spinning clouds of Co2 which covers its surface. These clouds hold heat in it that is why Venus gets so hot
- The clouds of venus reflect sunlight and that is why it appears so bright
- Almost equal to the size of the earth.
- It rotates backward (retrograde)
- Has no moons
- Distance from the sun is 0.7 AU

iii. Earth

- Only planet with life
- Has liquid water, oxygen, and moderate temperature
- Has one moon named Luna
- Has an ideal distance from the Sun.
- About its 30% of the surface is covered with land, while about 70% is covered by oceans.
- Completes its orbit in 365 days.
- Densest planet.
- The fifth largest planet
- Distance from the Sun is 1 AU

iv. Mars

- Called the "Red Planet" due to iron oxide
- Has thin Co2 atmosphere
- Has two moons (Phobos and Deimos)
- Has evidence of past water.
- Most explored planet after Earth
- The Second smallest planet
- Distance from the Sun is 1.5 AU

v. **Jupiter**

- Largest Planet
- The fastest rotating planet
- Has a strong magnetic field
- Has 90+ moons and Ganymede is the largest moon in our solar system
- Famous for Great Red Spot (giant storm)
- A gas giant
- Its distance from the sun is 5.2 AU

vi. **Saturn**

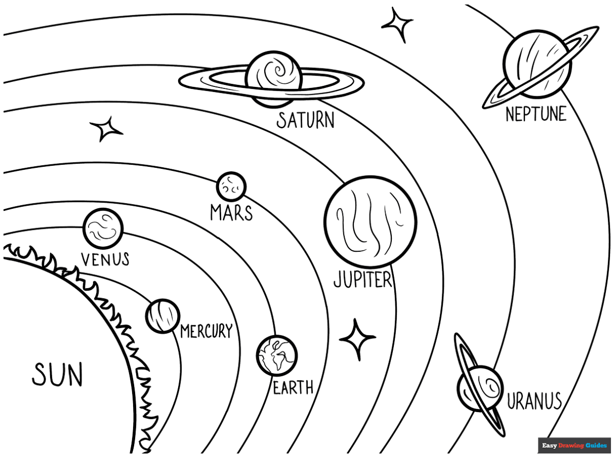
- The second biggest planet
- Also called the Ring Planet
- Surrounded by rings made of ice and dust
- The white spots on Saturn are believed to be powerful storms
- Has 80+ moons and Titan is the second largest moon in our solar system
- Has low density, it could float on water theoretically
- A gas giant
- Distance from the Sun is 9.5 AU

vii. **Uranus**

- Ice Giant
- Rotates on its side (tilted 98 degrees)
- Pale blue color
- Has faint rings
- It is a very cold planet
- Also known as the green planet
- Has 28 known moons
- Distance from the sun is 19.1 AU

viii. **Neptune**

- 8th Planet of solar system
- A dark blue and a very windy planet
- Has a great dark spot
- Moon triton orbits outward
- Has 16 known moons
- Distance from the Sun is 30 AU
- Known as the twin of Uranus due to diameter and mass similarities.



- Some facts about terrestrial planets
    - Made of rock and metal
    - Smaller in size
    - Few or no moons
    - No ring systems
    - Warm to hot because they are close to the Sun
    - Shorter orbital periods
    - Geologically active (volcanoes, mountains, tectonics)
    - Higher density
    - Slow rotation
    - Small masses and radii
- Some facts about jovian planets
    - Large gas-rich planets located far from the Sun
    - Have thick atmospheres, no solid surface, and low density
    - Large in size
    - Low density
    - Have many moons
    - All four have ring systems
    - Strong magnetic field
    - Has fast rotation
    - Large masses and radii
- Solar system also contains dwarf planets. There's a specific criteria for a planet to be recognized as a Dwarf planet and it was put forth by IAU
    - It must orbit the Sun
    - Has sufficient mass so it is nearly spherical in shape
    - Has not cleared its orbit of other debris
    - Is not a moon of another body/they should not be a satellite.
- The only difference between a planet and a dwarf planet is that a Dwarf planet has not cleared the area around its orbit, while a planet has.
- There are few famous dwarf planets such as **Pluto, Ceres, Eris, Haumea, and MakeMake.**
- Was Pluto rightly demoted?
    - It was once considered the 9^{th} planet till 2006
    - It is too small, even smaller than the earth's moon
    - Pluto meets the criteria of orbiting the Sun and having sufficient mass so it is nearly spherical in shape
    - But the third criteria, it failed to meet. It shares its orbital region within the Kuiper belt with many other objects of comparable size, including Eris, which is more massive than Pluto.

3. **Sun**

- Found at the heart of our solar system
- A yellow dwarf star and a hot ball of glowing gases
- Its gravity holds the solar system together, keeping everything from the biggest planets to the smallest particles of debris in its orbit.
- By far the largest object in the solar system
- Formed about 4.6 billion years ago from a cloud of gas and dust
- Contains 99.8% of the total mass of the Solar System
- Major source of heat energy on the earth surface.
- Sun's rays reach earth surface in 8 minutes and 20 seconds
- Nuclear fusion is the main source of Sun's energy
    - At its core, hydrogen atom fuses into helium and releases energy in the form of Gama rays
- Its elemental composition is
    - Hydrogen – 74 %
    - Helium – 24 %
    - Other elements – 2%
- The closest star to the earth after the sun is Proxima Centauri
- **The Interior structure of the Sun**

  i. Core
    - Is at the centre
    - The hottest region, where the nuclear fusion reactions occur.
    - The energy produced in the core powers the sun and produces all the heat and light the sun emits.
    - Here Hydrogen is converted into Helium and energy is released in the form of gamma rays.
    - The temperature here is around 15 million celsius.
    - It has a density of about 150 times the density of water.
    - Energy generated by the nuclear fusion in the core moves out as electromagnetic radiation.

  ii. Radiative Zone
    - Moving outwards, the next layer is the Radiative Zone
    - Radiative zone surrounds the core
    - Weighs almost half of the Sun
    - Energy travels through the radiative zone by radiation, but the photons are frequently scattered by particles in the gas and may take up to one million years to get through
    - Energy travelling outward is a very slow process.

  iii. Convection Zone
    - The outerlayer from the radiative zone
    - It comprises of 2% of the Sun's mass and 2/3rd of its volume
    - Heat from the radiative zone heats up the lower levels of the convective zone, then the hot plasma rises, gives off their heat and sinks back down again (convection currents).
- **The atmosphere of the Sun**

  i. Photosphere
    - The boundary between the Sun's interior and the solar atmosphere is called the Photosphere
    - It is the surface of the Sun
    - The visible "surface" of the sun
    - It is the source of sunlight that we receive.
    - Dark spots called **sunspots** appear here.
    - Temperature here is about 5,500 degree Celsius

ii. **Chromosphere**
- It lies above the photosphere
- It gives a reddish glow when seen during a total solar eclipse
- It is the source of solar flares and prominences
- Temperature can be up to 20,000 degree Celsius

iii. **Corona**
- The outermost layer
- Very thin but extremely hot
- Temperature here is around 1 to 2 million degree Celsius
- It emits solar wind
- Visible during total solar eclipse as a white halo

➢ **There are certain Key Solar Phenomena**

4. **Life cycle of a Star**

   i. **Nebulae (Birthplace of Stars)**
   - Stars begin in a nebula
   - Nebula is a large cloud of gas and dust in space
   - Mostly formed from supernova remnants or interstellar clouds
   - Gravity pulls the gas together, forming a dense region.
   - Temperature rises as particles compress, initiating the protostar phase.

   ii. **Protostar – formation phase**
   - A hot, contracting cloud of gas that is not yet a true star
   - It radiates energy in the infrared spectrum
   - This stage lasts tens of millions of years for a sun-like star.
   - A protostar becomes stable and enters the main sequence stage once the fusion begins.

   iii. **Main Sequence Stage**
   - A star spends its 90% of its life in this stage
   - During this phase the protons of Hydrogen are converted into atoms of Helium. This reaction is exothermic
   - Hydrogen fusion begins and helium is formed and energy is given off.
   - It is the longest phase in a star's life
     - For sun-like stars it stays in this phase for 10 billion years
     - For massive stars it stays in this phase for a few million years.
   - Once all the hydrogen fuses, only helium would remain at its center.
   - The remaining helium is used in the next phase.
   - Sun is expected to be in this stage for 10 billion years and only 5.5 are left.

   iv. **Triple Alpha Phase/ Helium-Fusion stage/ The Giant Phase**
   - 3 Helium atoms form a Carbon atom
   - This stage produces an enormous amount of heat, light, and energy
   - This stage is short as compared to the main sequence stage
   - In about 5.5 billion years, when the Sun will enter the helium burning phase it will expand 250 times its present size and will start to gobble up the inner planets.
   - The end of the red giant phase depends on the mass.

   v. **If the star is high mass and massive**
   - Massive stars will expand into **red super giants**
     - Core will start to fuse heavier elements
     - Radius can be thousands of times larger than the Sun
     - At the end the core cannot fuse iron. So the core collapses under gravity and outer layers will explode
   - **Supernova will occur**
     - Once the outer layer explode, there would be heavy elements produced such as gold and uranium
     - This would be an extremely bright scenario
   - **Neutron Star and Black Hole**
     - If mass of the core is between 1.4 and 3 Solar Mass, a neutron star would be formed
     - If the mass of the core is above 3 Solar Mass then a black hole would be formed.

   vi. **If the star has low or medium mass**
   - First a **Red Giant** will be formed
   - As helium fusion begins in the core, carbon and oxygen would be formed
   - Later on there would be no helium left at the core.
   - The luminosity would increase and surface temperature would decrease
   - The majority of the leftover elements would be fusable and would become energy.

- It would regress and would go on to form a **blue dwarf** and later on within few million years it would turn into a **white dwarf.**
- Black dwarf is a hypothetical stage.

5. International Astronomical Union

- The world's leading organization of professional astronomers
- Founded in 1919, Brussels, Belgium
- The purpose is to promote astronomy through international cooperation and standardize astronomical nomenclature – **astronomy is** the study of objects in the night sky
- In 2006 it redefined the definition of planet, leading to Pluto's demotion to a dwarf planet
- It has standardized naming of celestial bodies, exoplanets, stars, and asteroids.
- Adopted AU as the standard measure of distance in the Solar System
- Astronomical Unit is the average distance between Earth and the Sun

i. Astronomical Unit of Time

- Derived from AU and the speed of light (c)
- This concept is standardized by the IAU for the light-time calculations in the solar system
- AU of time is the time taken for light to travel the distance of 1 AU

ii. Astronomical Unit of Mass

- Defined using the Solar Mass ($M_\odot$)
- Adopted by IAU for orbital calculations and stellar comparisons
- Used in Kepler's laws and Newtonian calculations
- Mass of other stars, planets, or systems is often compared to 1 Solar Mass.

6.