Summary Notes - Topic 15: Our Place in the Galaxy

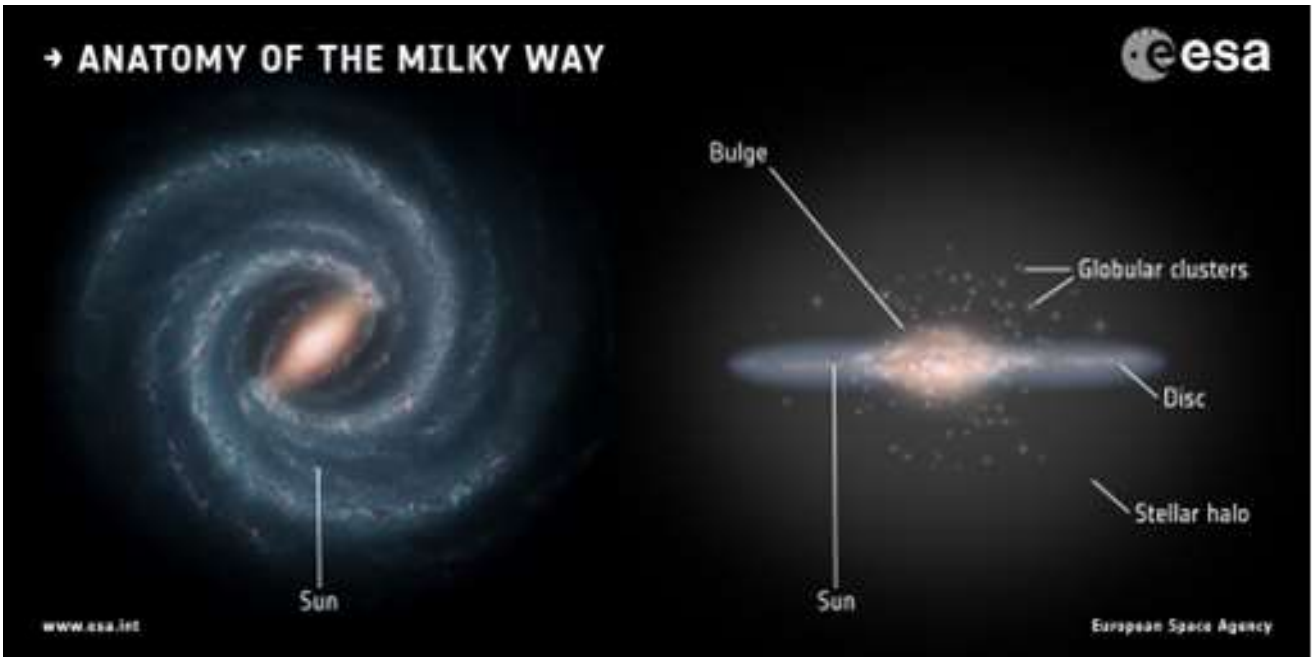
15.1 The Milky Way as Seen from Earth

- Appears as a **faint, milky band** across the sky due to billions of distant stars.
- Best observed with **binoculars or a small telescope** under dark skies.
- Dense regions are part of the **galactic plane**, with dark patches caused by interstellar dust.

- **Study Tip:**
  - Try to locate the **Galactic Center** in **Sagittarius** for the brightest region of the Milky Way.

15.2 Structure of the Milky Way

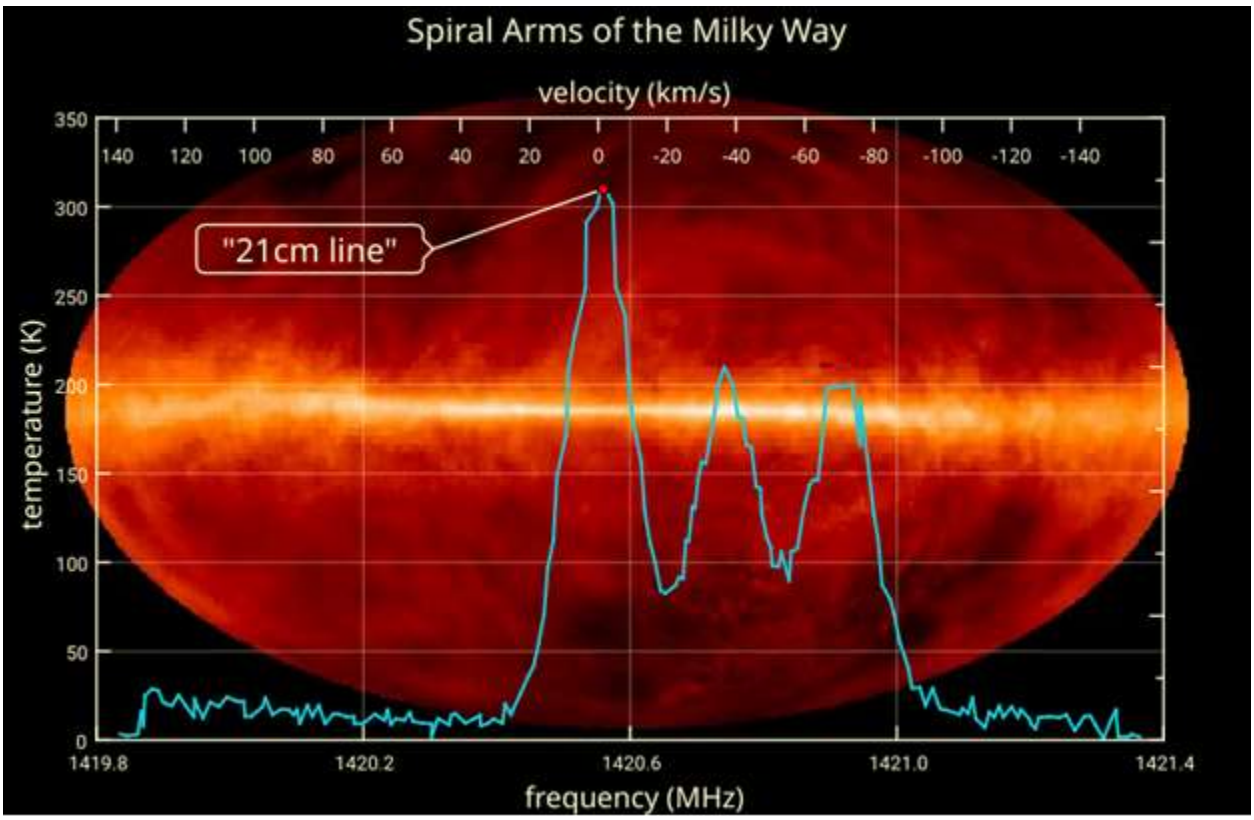
- **Size**: ~100,000 light-years in diameter.
- **Shape**: **Barred spiral (SBb)** galaxy.
- **No of stars**: 100-400 billion
- **Sun's Location**: ~27,000 light-years from the center, in the **Orion Arm**.
- **Dust & Star Formation**: Found in **spiral arms**, where new stars are born.
- **Globular Clusters**: Found in the **halo**, containing some of the oldest stars.



- **Study Tip:**
  - Memorize the **key components**: bulge, disk, halo, spiral arms.

15.3 Using 21 cm Radio Waves to Study the Milky Way

- **Visible light is blocked** by interstellar dust, making optical observations difficult.
- **Neutral hydrogen (HI) gas** emits **21 cm radio waves**, which penetrate dust.
- Used to **map** the **structure** and **rotation** of the Milky Way.



- **Study Tip:**
  - 21 cm radio waves help determine the **shape and motion** of the galaxy.

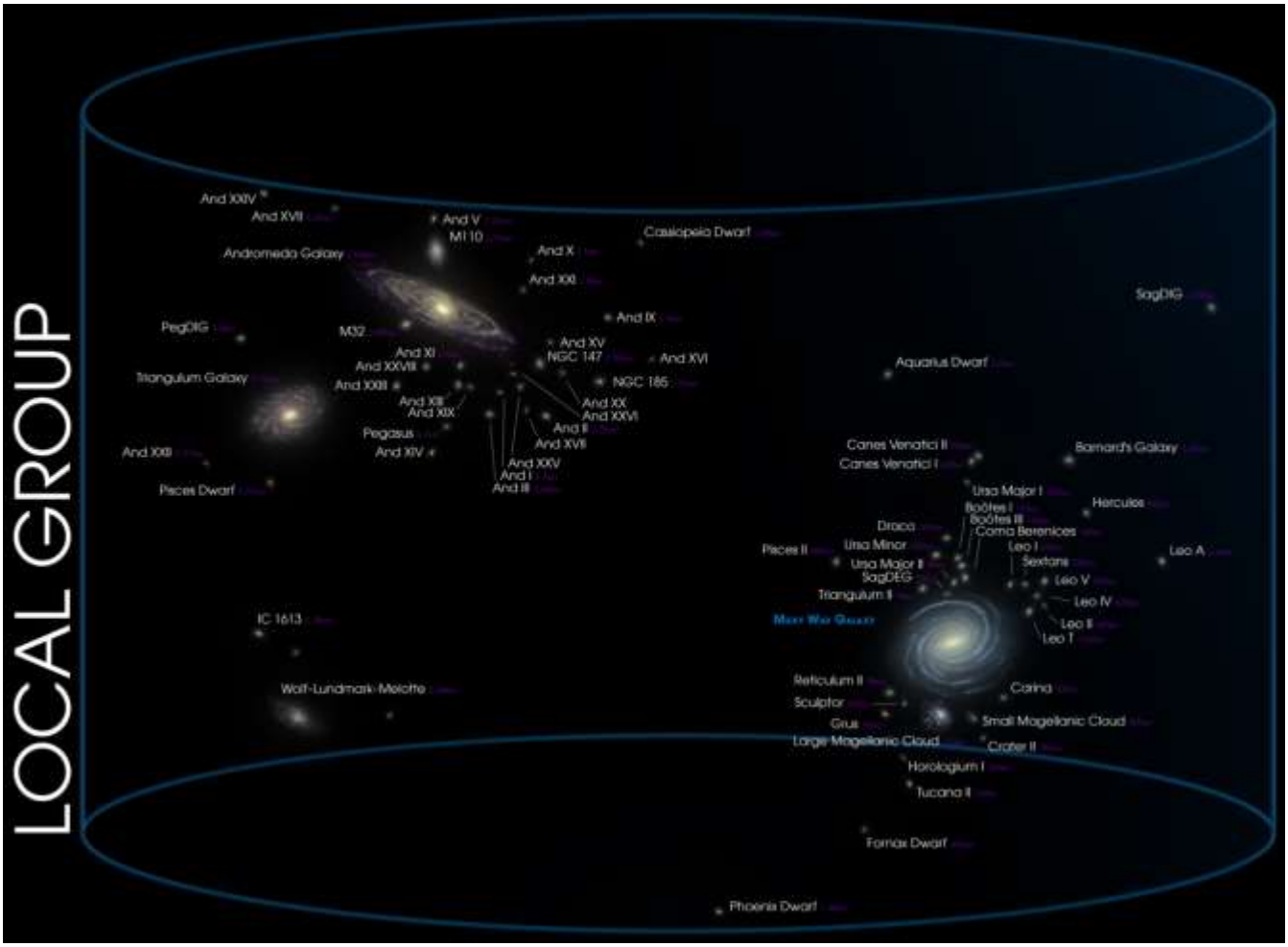
15.4 The Local Group

- A **gravitationally bound** group of galaxies that includes the Milky Way.
- Contains **three larger galaxies** – Andromeda, the Milky Way and the Triangulum Galaxy, with other, mostly dwarf galaxies, orbiting these
- The exact number of galaxies in the Local group is unknown, but it is at least 134.
- The Local Group has a **dumbbell** shape, with Andromeda and the Milky Way (along with their respective satellites) forming the 'lobes' of the dumbbell.

- **Study Tip:**
  - Know the **Local Group's members** and their relation to the Milky Way.

15.5 Key Galaxies in the Local Group

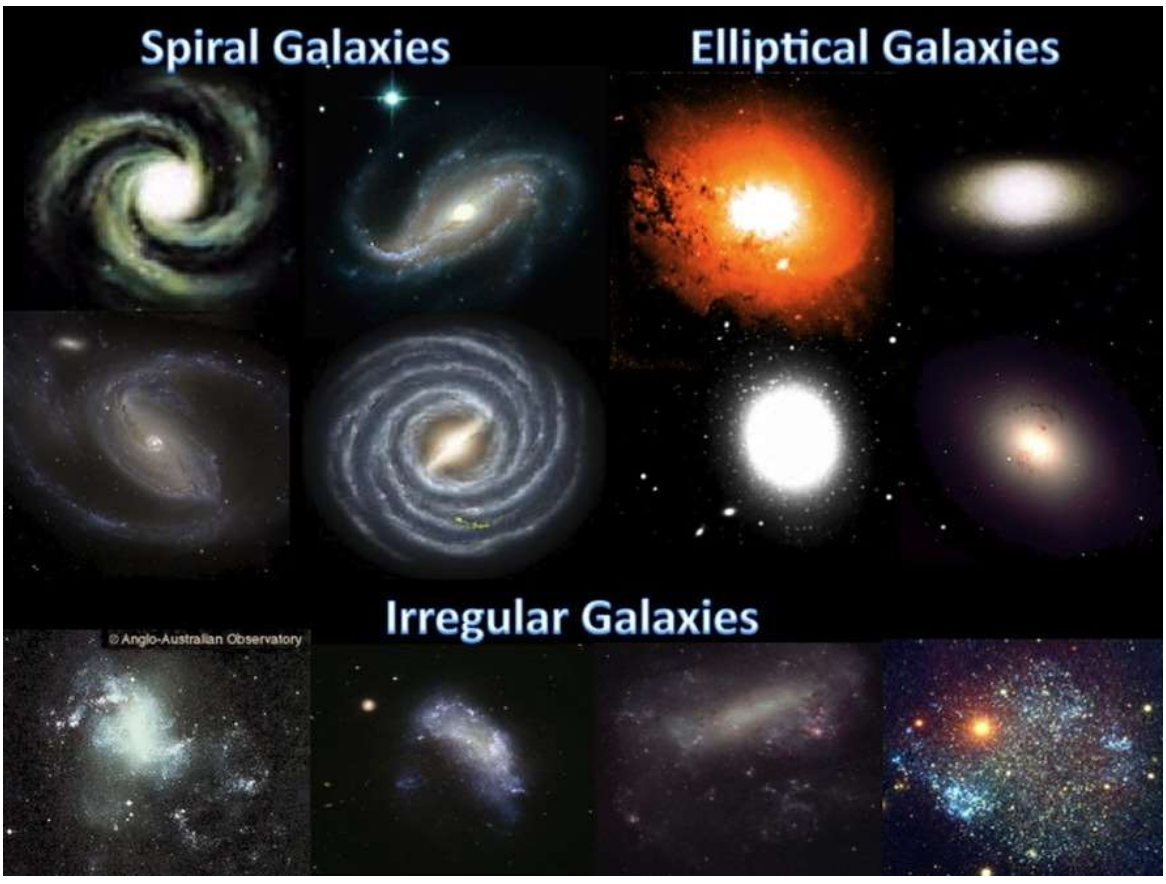
- **Andromeda Galaxy (M31)**: Largest in the Local Group, ~2.5 million light-years away.
- **Milky Way**: The second largest galaxy in the Local Group, in which the Solar System is located.
- **Triangulum Galaxy (M33)**: The third largest galaxy in the Local Group. A smaller spiral galaxy, possibly a satellite of Andromeda.
- **Large & Small Magellanic Clouds (LMC & SMC)**: Irregular dwarf galaxies orbiting the Milky Way.



- **Study Tip:**
  - Andromeda is moving **toward** us at a speed of 123 km/s and will **merge** with the Milky Way in ~4.5 billion years.

15.6 Hubble Classification of Galaxies

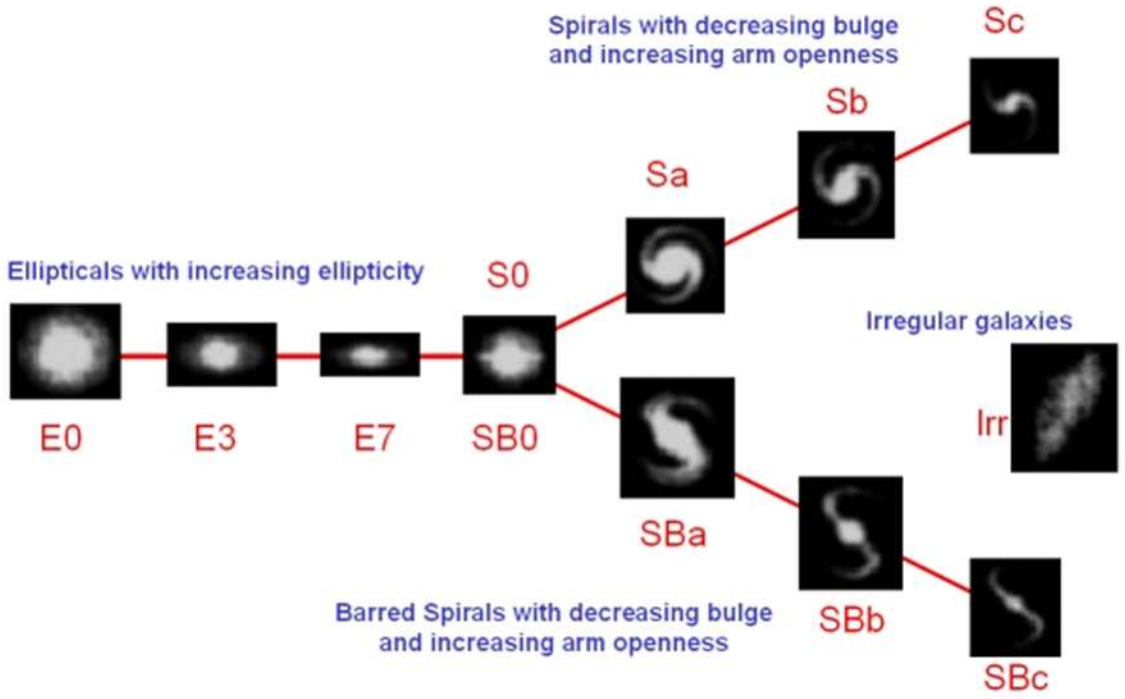
- **Spiral (S)**: Disk-shaped with spiral arms (e.g., Milky Way, Andromeda).
    - Star formation takes place in the spiral arms, so these are dominated by younger stars
    - Older stars are found in the bulge
    - Spiral galaxies appear blue overall due to a large amount of dust
- **Barred Spiral (SB)**: Similar to spiral but with a **central bar** (e.g., Milky Way).
- **Elliptical (E)**: Round to elongated, little gas or dust
    - Very little star formation, so mostly older stars
    - Often yellow-red in colour
    - Thought to have formed from galaxies merging
- **Irregular (Irr)**: No defined shape, usually rich in gas and young stars.
    - High rates of star formation



- **Study Tip:**
    - Know the **differences** between these galaxy types.

15.7 Hubble's 'Tuning Fork' Diagram

- A diagram used to **classify galaxies** based on their **shape** and **structure**.
- **Spiral galaxies** branch off the main stem, with **barred spirals** in a separate branch.
- **Elliptical galaxies** form the base.
- **Irregular galaxies** are not placed on the diagram.



- **Study Tip:**
  - Be able to **draw** or **explain** Hubble's diagram.

15.8 The Milky Way as a Barred Spiral (SBb)

- **SBb classification** means:
  - A **bar** in the center.
  - Moderately **tightly wound spiral arms**.

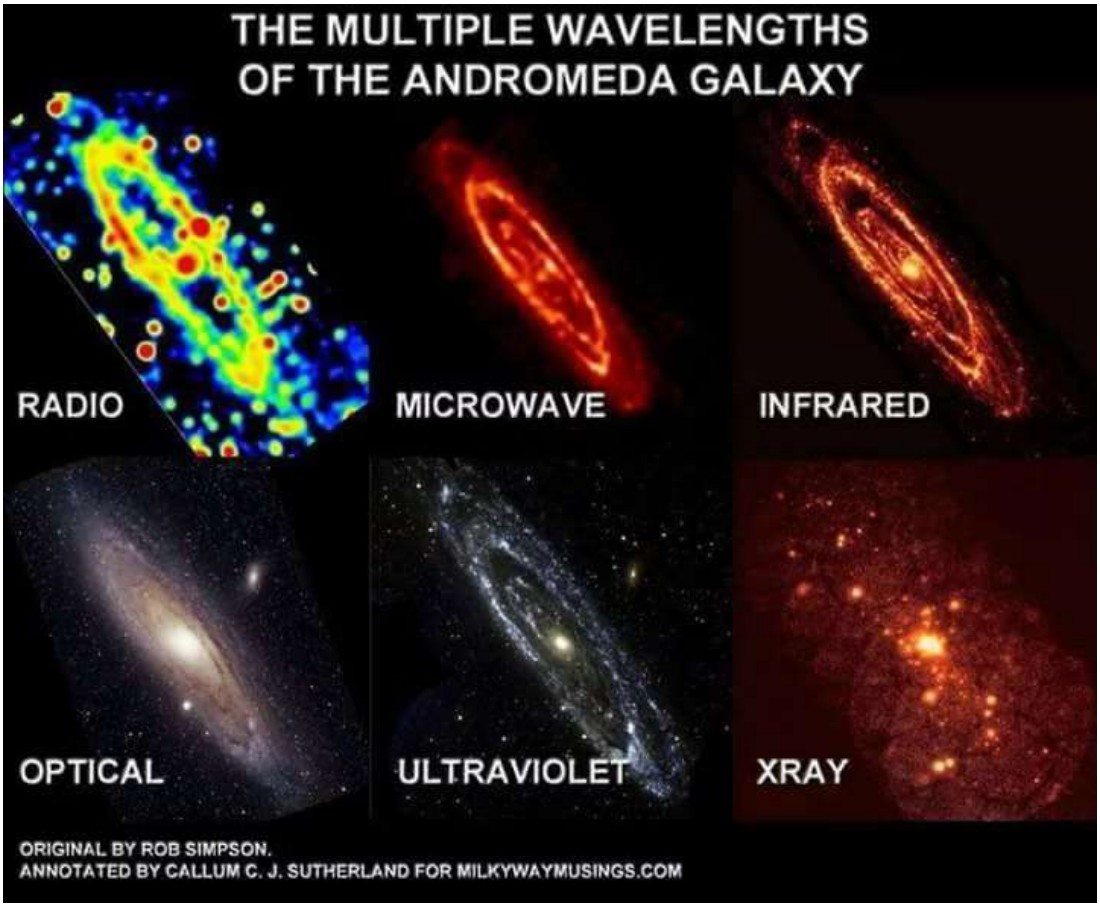
- **Study Tip:**
  - Remember **SBb** as the Milky Way's type.

15.9 Galaxies That Emit High Energy Radiation

- Some galaxies **emit large amounts of radiation** beyond visible light.
- Detected in **radio, X-ray, and gamma-ray wavelengths**.

🔹 **Study Tip:**

- These galaxies are often **active galaxies** with supermassive black holes.



15.10 Active Galactic Nucleus (AGN) & Supermassive Black Holes

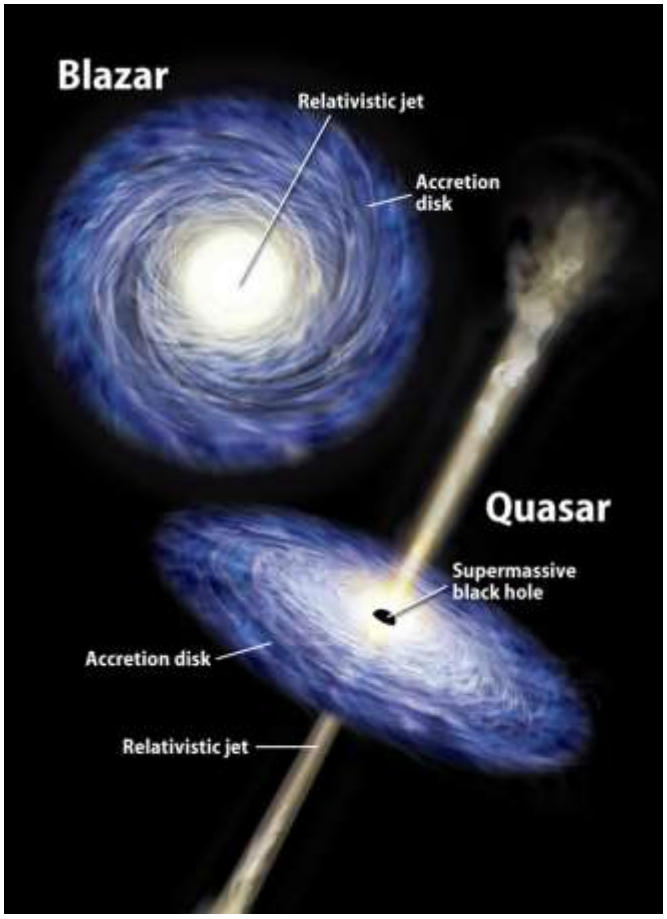
- AGNs are **bright central regions** powered by material **falling into a black hole**.
- Extremely energetic due to **accretion disks** around black holes.

🔹 **Study Tip:**

- AGNs are found in the **centers** of some galaxies.

15.11 Types of Active Galaxies

- **Seyfert Galaxies**: Spiral galaxies with **bright central AGNs**.
- **Quasars**: **Most luminous AGNs**, extremely distant.
- **Blazars**: A quasar viewed from **directly along its jet**, making it appear even brighter.



- **Study Tip:**
  - Quasars are **the brightest** and **most distant** objects in the universe.

15.12 How We Study AGNs Across the Electromagnetic Spectrum

- **Radio waves** detect jets.
- **Infrared** shows dust and warm material.
- **Visible light** studies stars and gas clouds.
- **X-rays & Gamma rays** detect matter falling into black holes.

- **Study Tip:**
  - Different wavelengths reveal different **features** of AGNs.

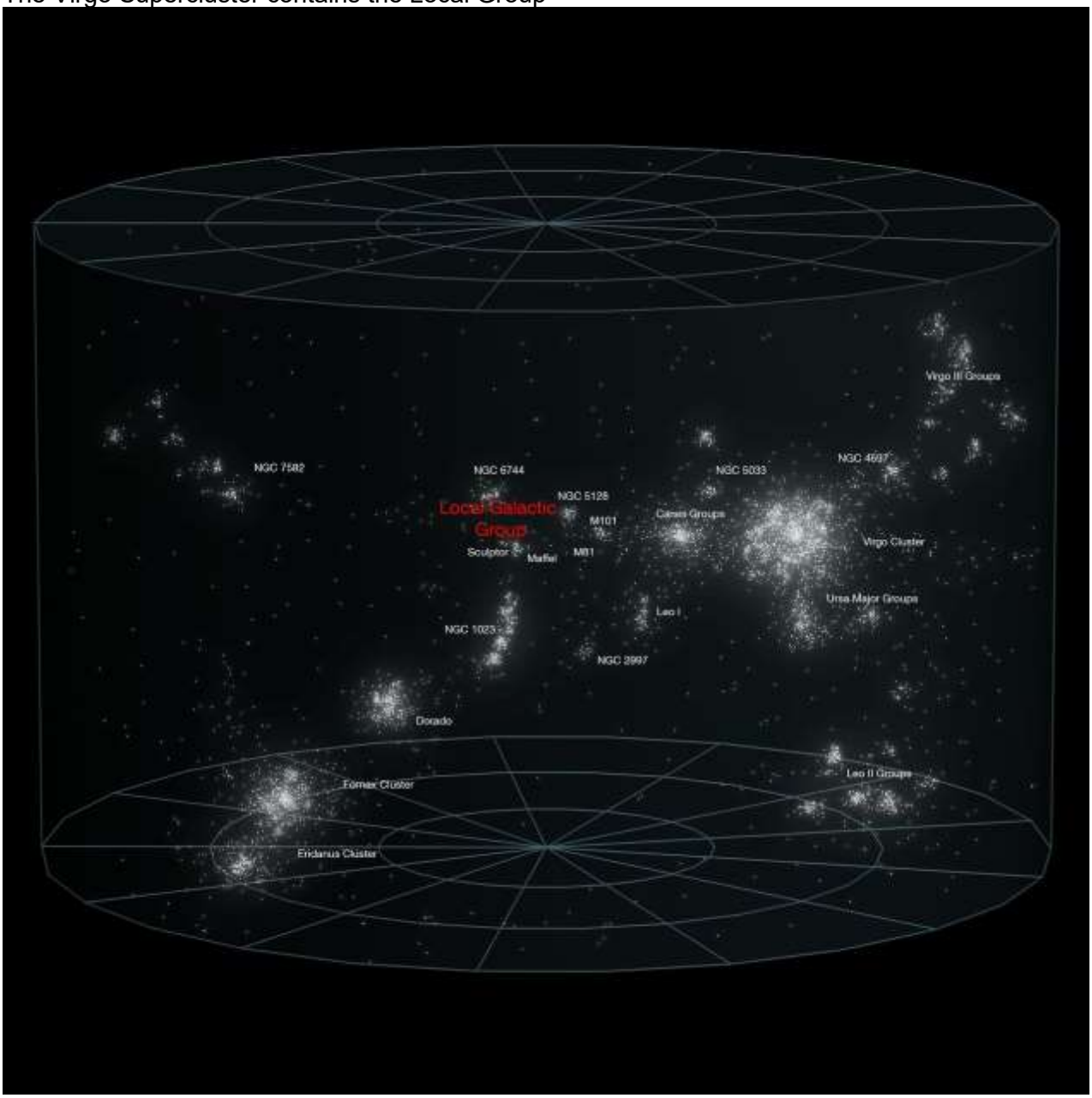
15.13 Galaxy Clusters & Superclusters

- Galaxies are grouped into **clusters**, which form even larger **superclusters**.
- The **Local Group** is part of the **Virgo Supercluster**.

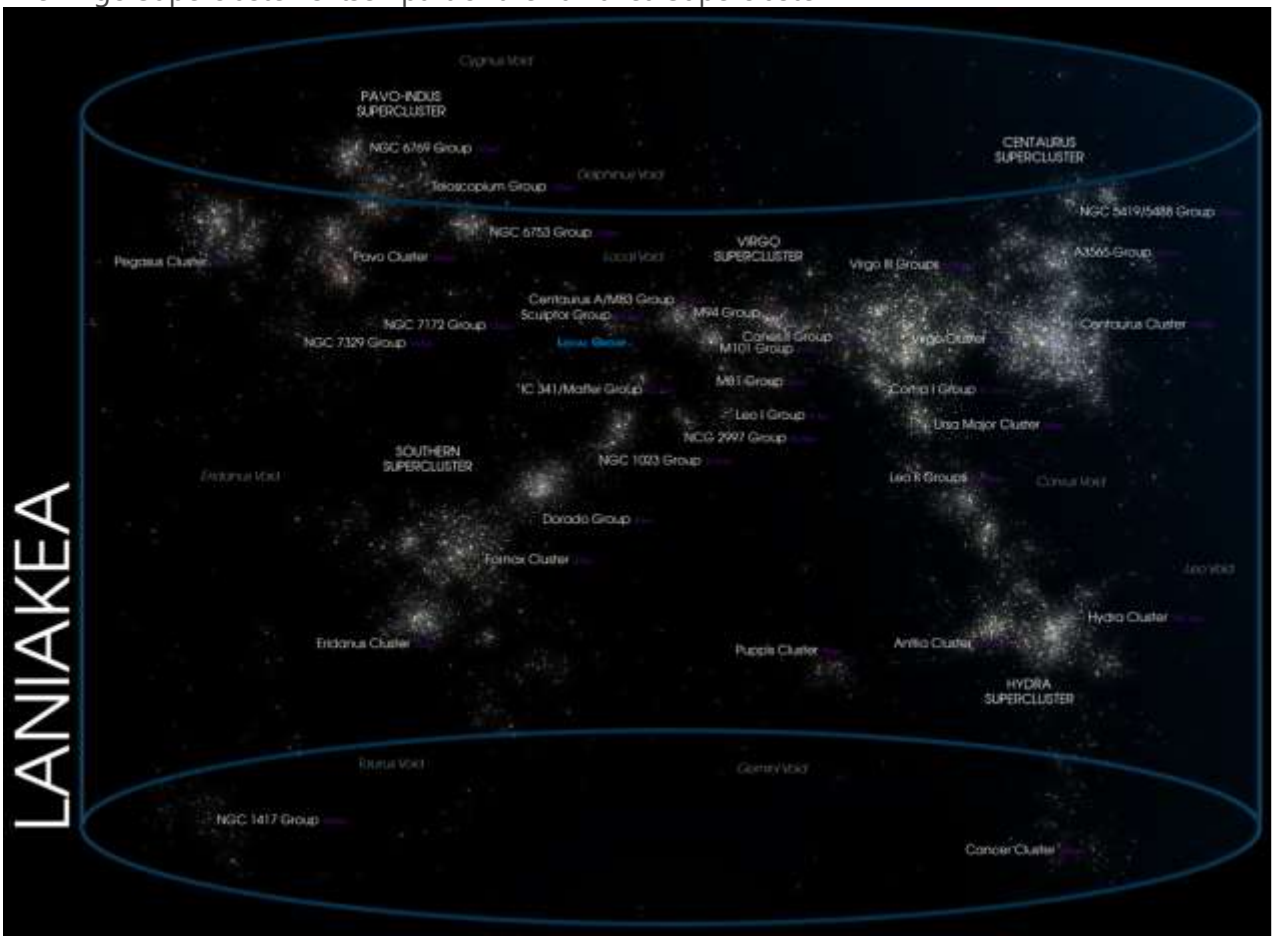
🔹 **Study Tip:**

- Superclusters are the **largest** known structures in the universe.

The Virgo Supercluster contains the Local Group



The Virgo Supercluster is itself part of the Laniakea Supercluster



15.14 Theories of Galaxy Formation & Evolution

1. **Bottom-Up Model**: Small gas clouds merged to form galaxies.
2. **Top-Down Model**: Large clouds fragmented into galaxies.
3. **Modern Theories**:
    - Galaxies formed **early in the universe** (~13 billion years ago).
    - **Dark matter** played a role in their formation.
    - Galaxies **change over time** due to **mergers and interactions**.

- **Study Tip:**
    - Understand that galaxy formation is still an **active area of research**.

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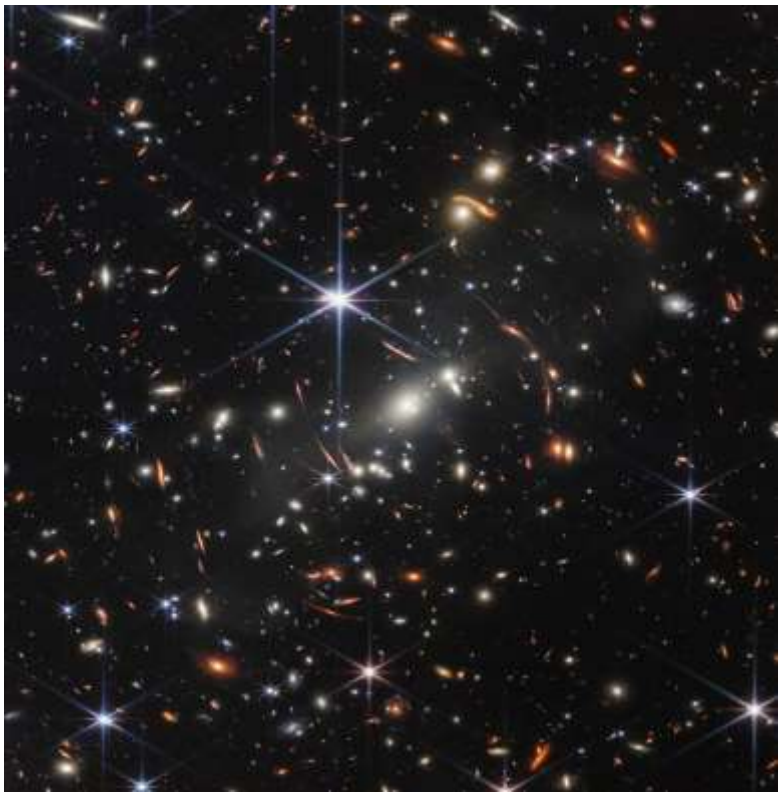

The James Webb Space Telescope's First Deep Field image