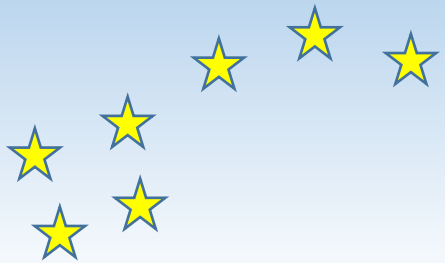


Galaxies

Physical Sciences

Broward College

Prepared for AST 1002

Horizons in Astronomy

Objectives

- What is a galaxy?
- Types of galaxies
- Anatomy of a galaxy
- Active Galaxies
- Galactic Distances
- Clusters of galaxies and Galactic Formation

What is a Galaxy?

- A galaxy is a group of stars that are gravitationally attracted to each member of the group.
- A galaxy has one billion and more stars.
- A galaxy has a dense, hot nucleus with diffuse nebulae and stars orbiting the nucleus.
- Most galaxies are believed to have a central black hole in the nucleus as a central energy producer.

Types of Galaxies

- Spiral
- Elliptical
- Irregular
- Peculiar

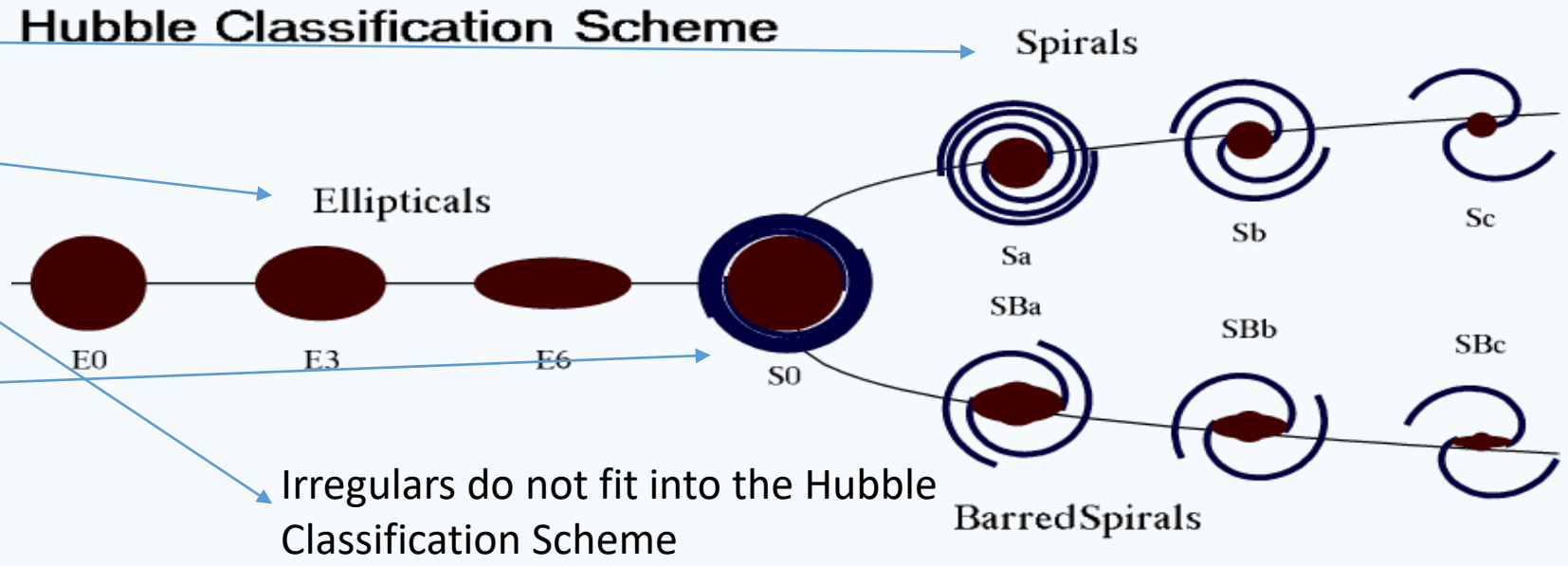


Figure 1. Hubble Classification Scheme (Wiki)

Elliptical and Spiral Galaxies

M 51 Spiral Galaxy

Figure 2. M 51 (Van Werven, 2015)

M 87 Elliptical Galaxy

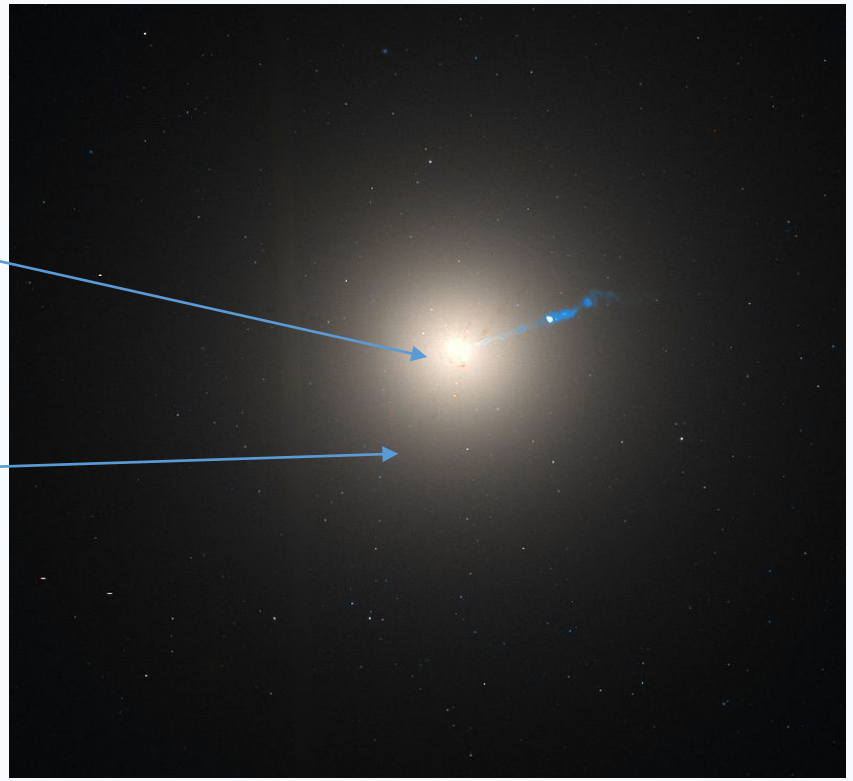


Figure 3 M 87 (Wiki)

Irregular Galaxies

M 82 Irregular Type I Galaxy – Interacting galaxies making one galaxy

Figure 4. M 82 (Van Werven, 2015)

Large Magellanic Cloud Irregular Type II Galaxy – A billion or more randomly space stars

Figure 5. Large Magellanic Cloud (Wiki)

M 104 Peculiar Galaxy – Strange Object (SO)

Figure 6. M 104 (Wiki)

What makes a galaxy active?

- An active galaxy is a galaxy with a strong radio signal ratio with respect to the optical in the nucleus (usually around 30% radio to optical flux).
- Active galaxies have unusually bright nuclei that tend to outshine the diffuse material that is orbiting the nucleus.
- Jets of material are observed to originate from the nuclei of active galaxies.
- Active galaxies exist are large distances (100 Mpc – 10 Gpc) as compared to normal galaxies.
- Also, they have large variations in brightness as compared to normal galaxies.
- All the observations suggest that Active Galaxies are the young precursors to nearby normal galaxies.

Extended versus Stellar Active Galaxy

M 87 Elliptical – Extend Active Galaxy

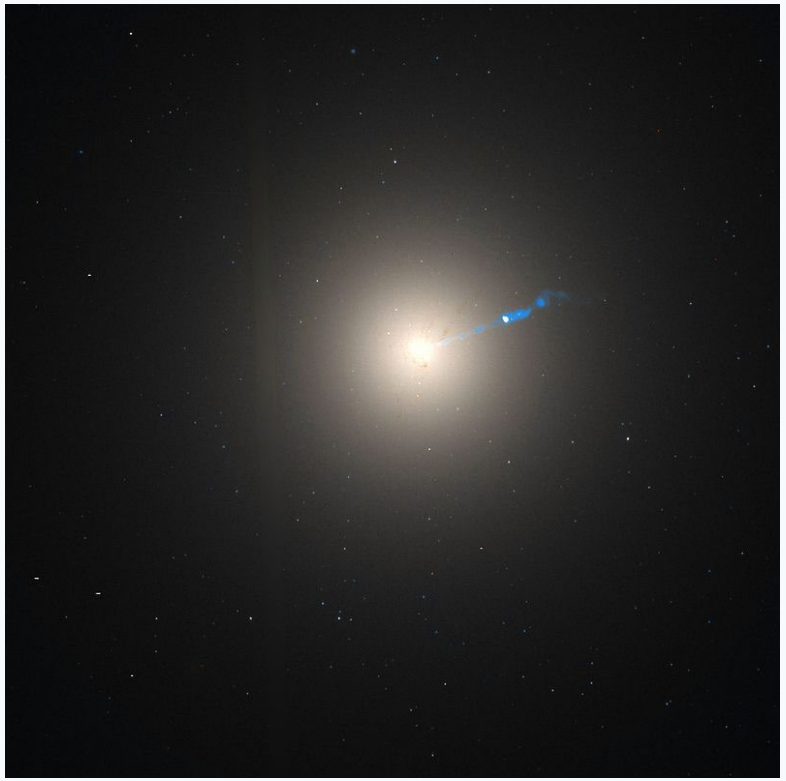


Figure 7. M 87 (Wiki)

BL Lacertae Object – Stellar Object

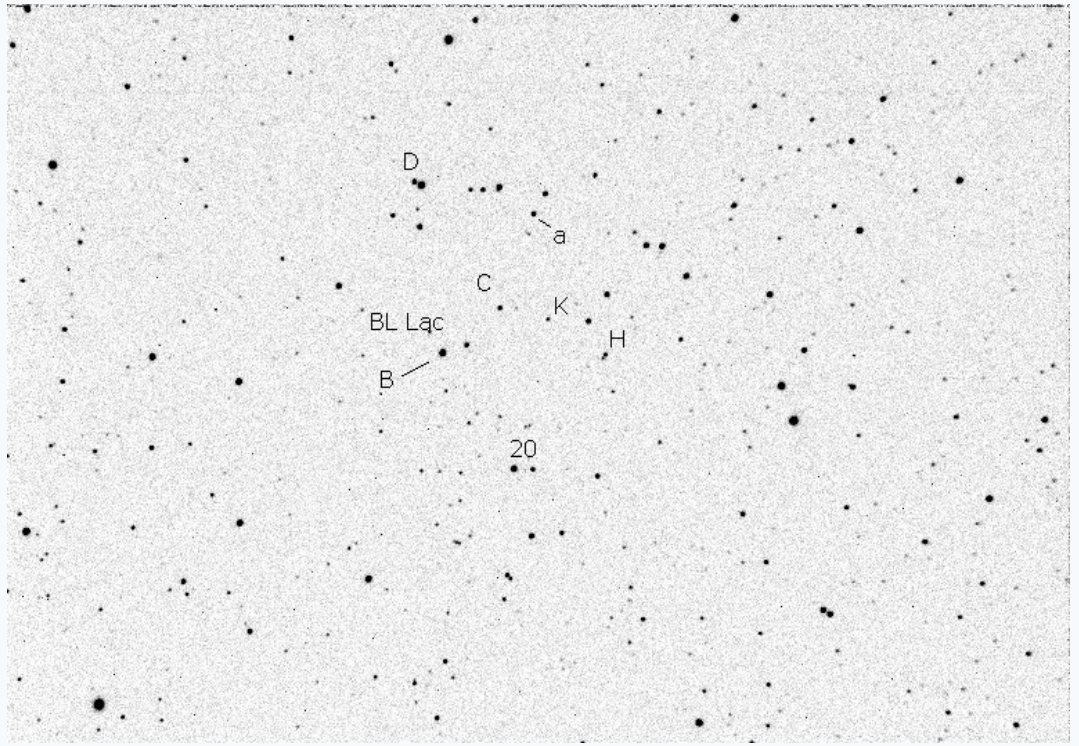


Figure 8. BL Lacertae Object, Buehler Observatory, Emily Howard

M 87 Core & Disk

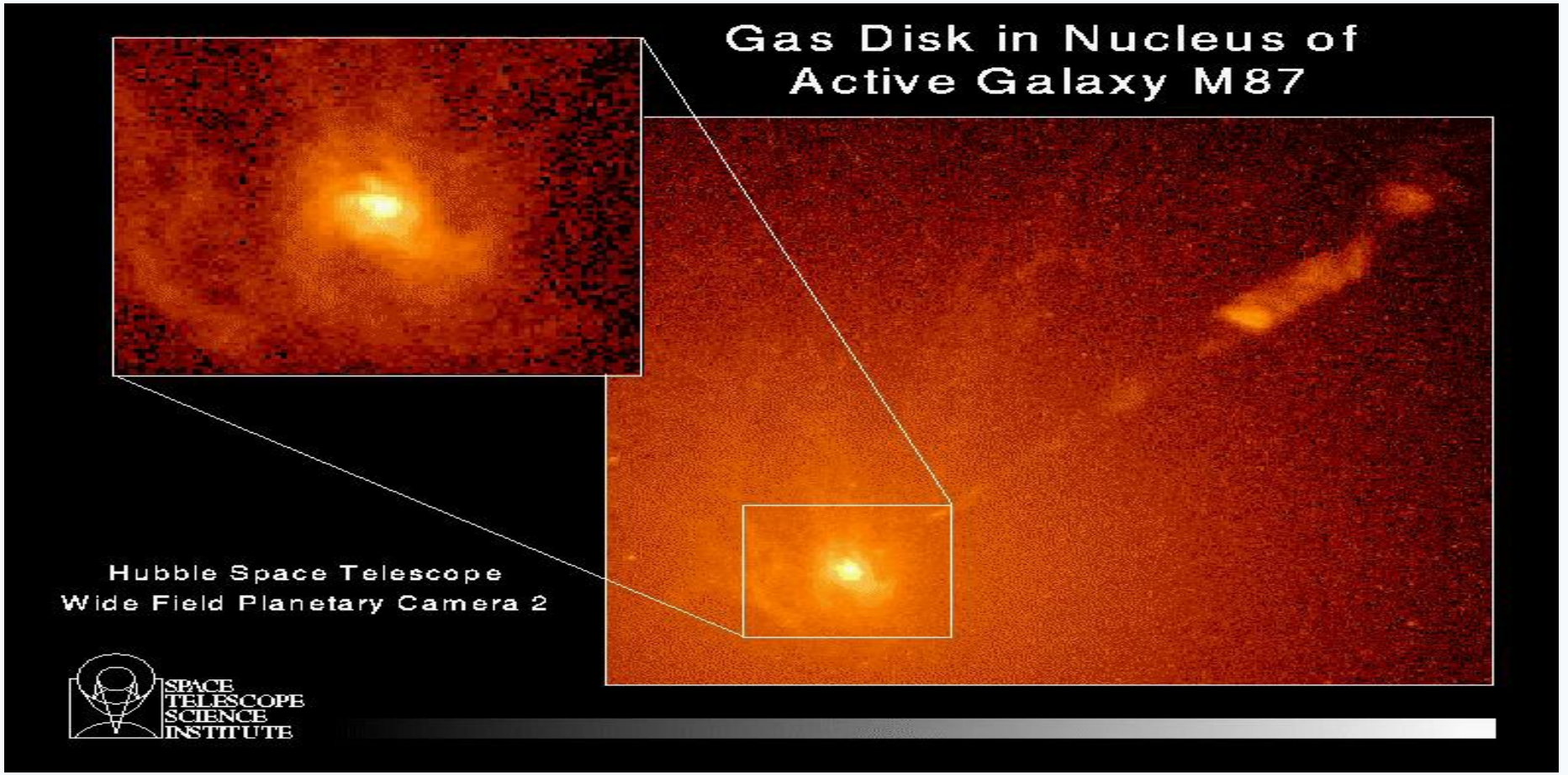


Figure 9. Core of M 87 (Ford, 1994)

Active Galactic Nuclei Modeling

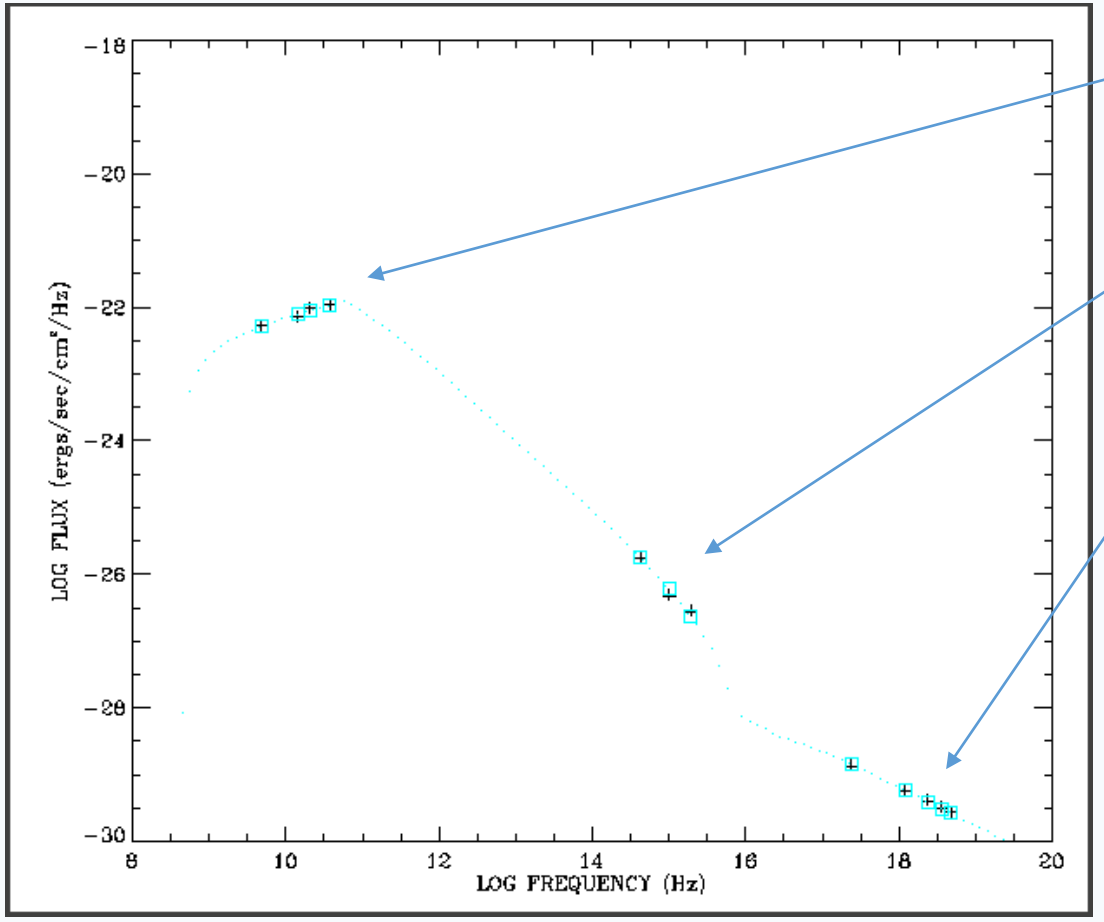


Figure 6. Power Spectrum of 3C 345 (Webb, 1994)

Dusty Torus - Radio

Accretion Disk - Visible

Relativistic Jet – X-Ray

- The dimmer the region, the smaller the region is in the physical world.
- The different energies are produced when particles are acceleration and up-scattered when colliding with other particles.

Types of Active Galactic Nuclei

- Active Galactic Nuclei (AGN) are the nuclei of active galaxies.
- The types of AGN are Seyfert Galaxies, N-Galaxies (LINERs), Quasi-Stellar Objects (QSOs), and BL Lacertae Objects (BL Lacs).
- Seyferts and LINERs appear as extended objects such as spiral galaxies and elliptical galaxies, respectively.
- QSOs and BL Lacs are so bright in the optical that they appears as stellar objects rather than extended objects as galaxies.

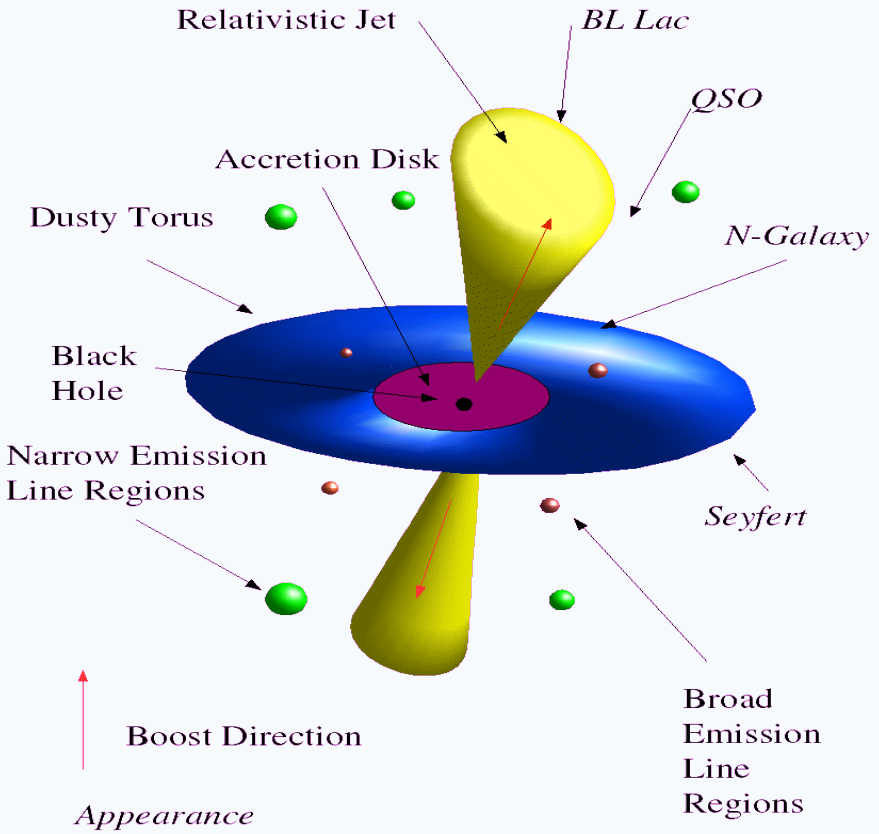


Figure 10. Active Galactic Nuclei

Radio Map and Spectra of Active Galactic Nuclei

Radio Map of M 87 from Very Large Array and Baseline

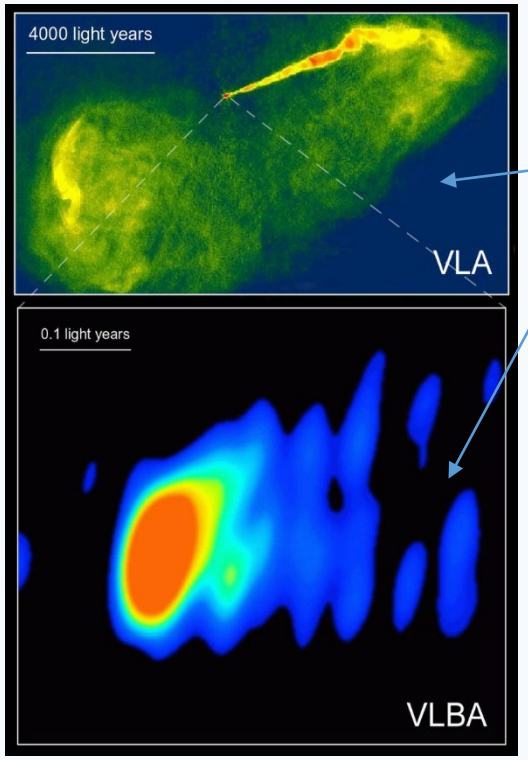


Figure 11. Radio Map of M 87 (Wiki)

- AGN have large radio lobs and knots unlike normal galaxies.
- They also have emission spikes unlike stellar objects which only have absorption spikes.

Spectrum of BL Lacertae from the Hale Telscope

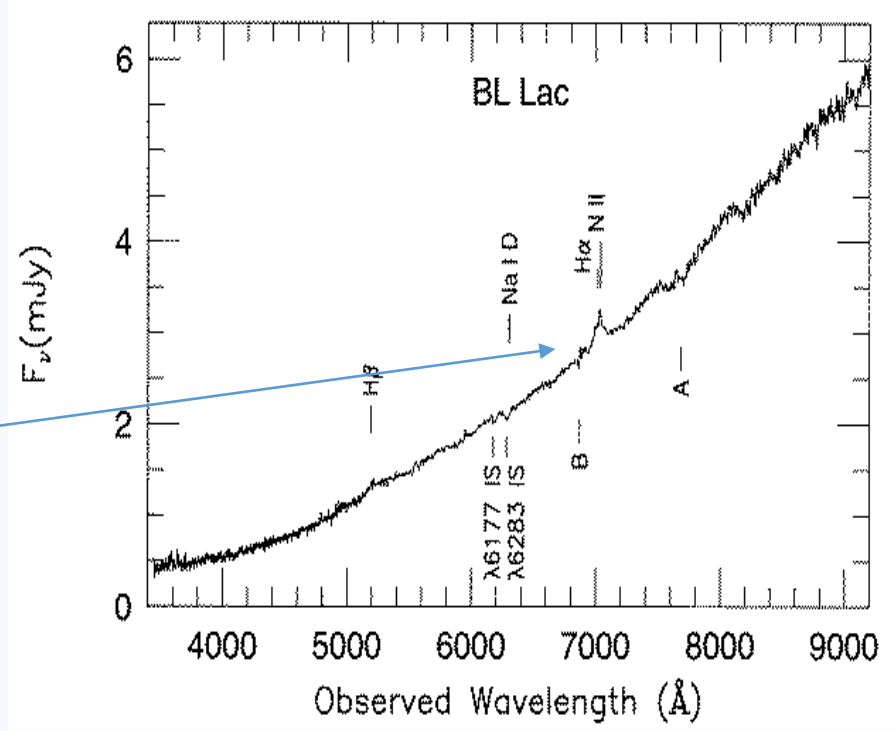


Figure 12. Spectrum of BL Lacertae (Vermuelen et al., 1995)

AGN Variability

- Long Term: Period of Years
  - Cause: No known cause
- Short Term: Period of Months
  - Cause: Matter the size of stars is suddenly accreted into black hole.
- Intraday: Period of Days
  - Cause: No known cause
- Microvariability: Period of Hours
  - Cause: Hot spots on either the accretion disk or jet.

Variability of BL Lacertae

Long Term

Short Term

Microvariability

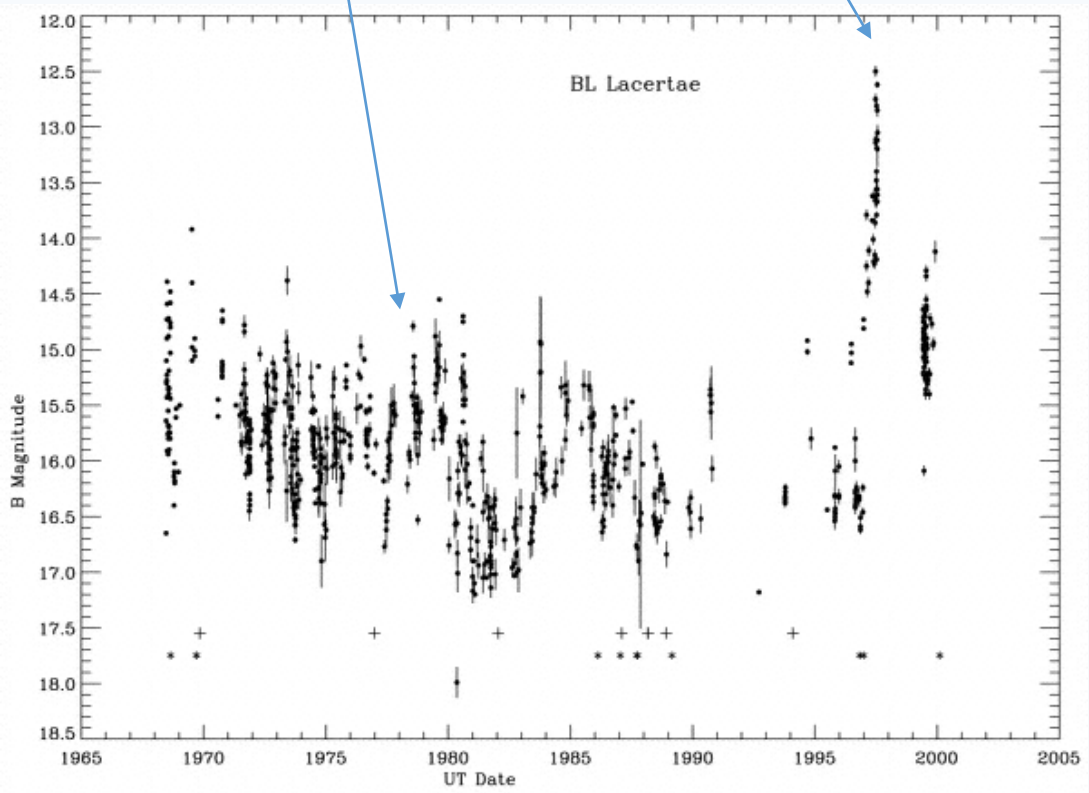


Figure 13. Long-Term Lightcurve of BL Lac (Howard et al., 2004)

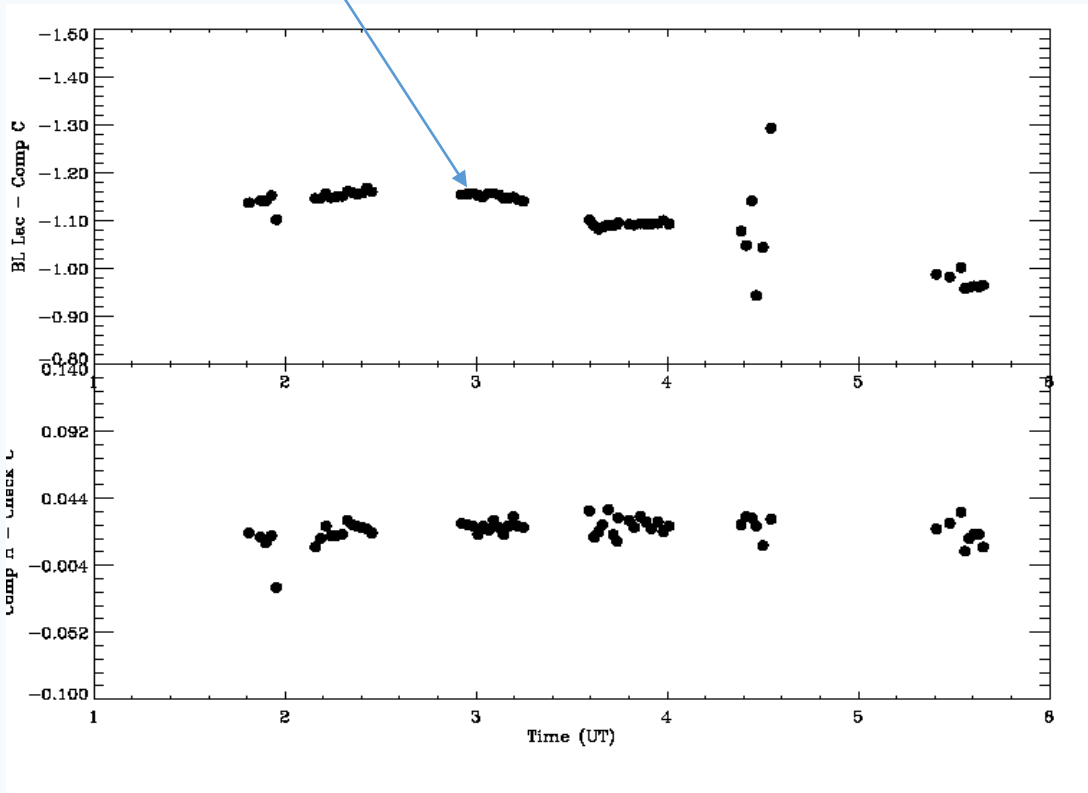
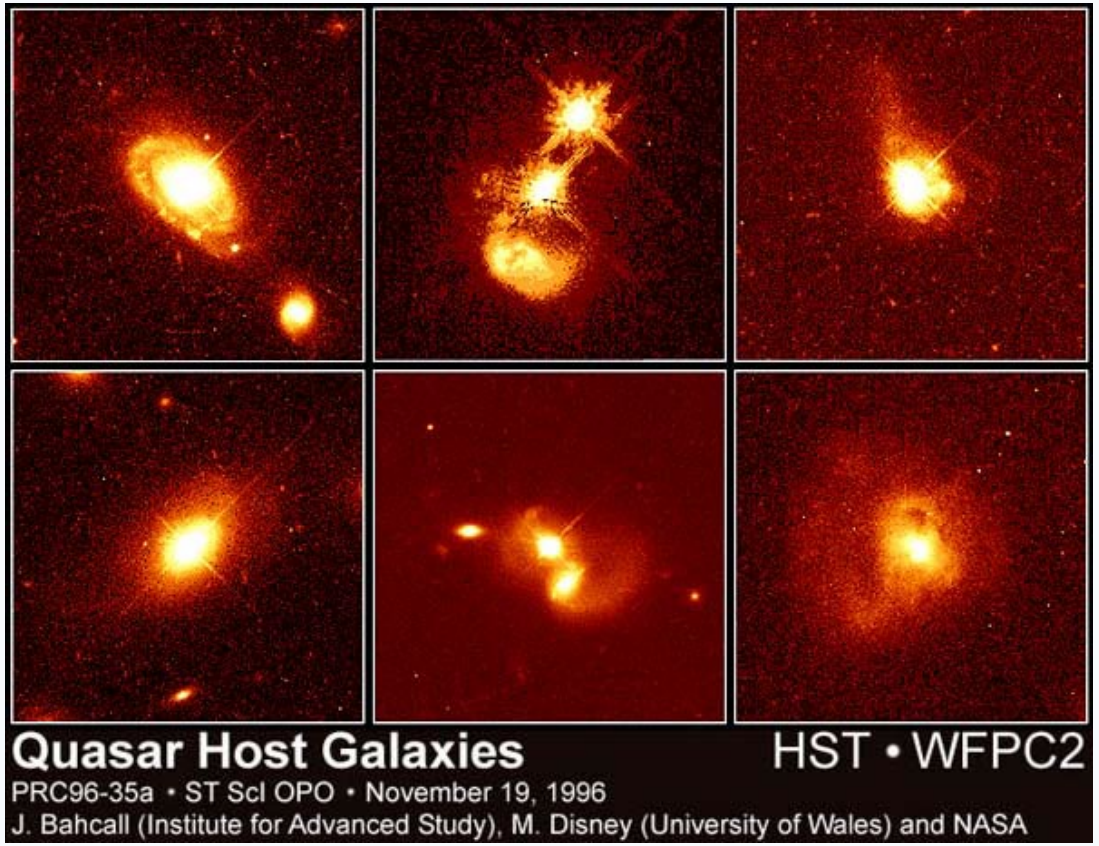


Figure 14. Microvariablity of BL Lac (Howard et al., 2004)

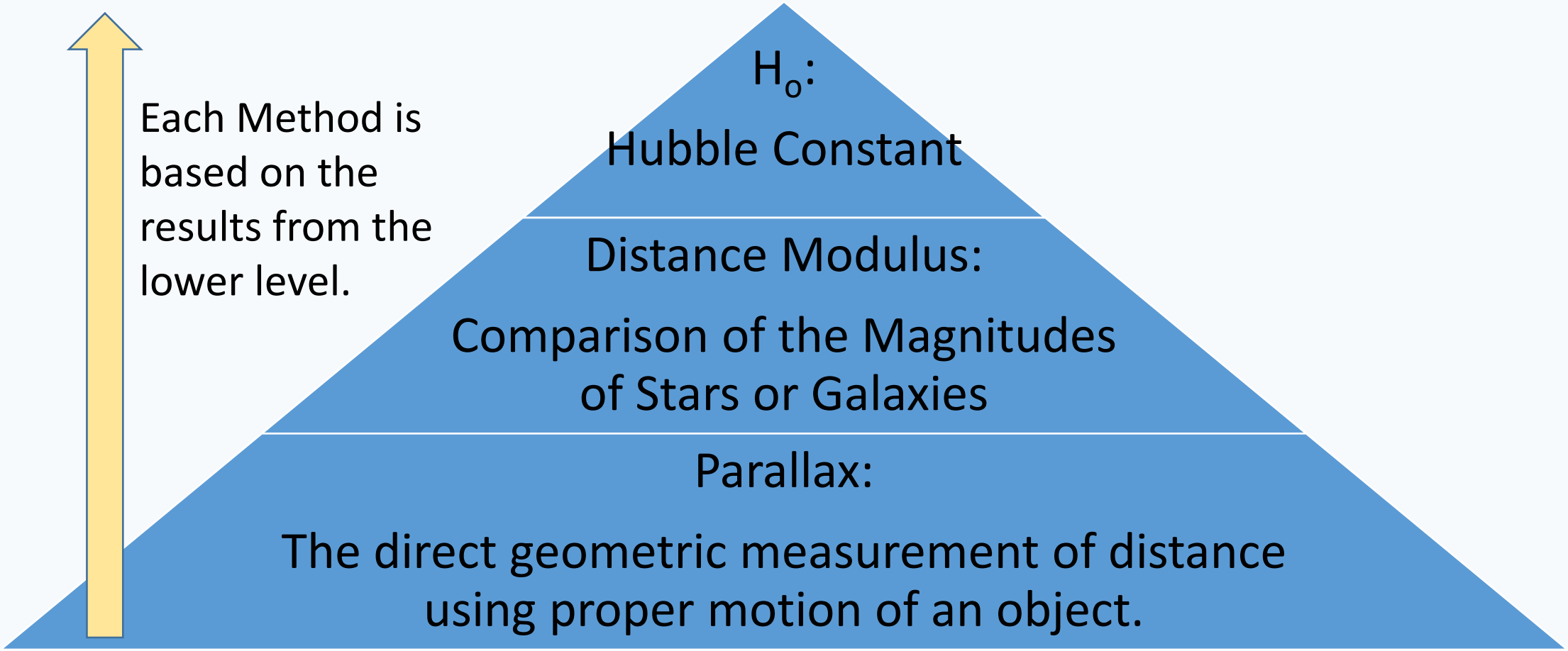
Host Galaxies of Quasars



- Many of the active galaxies seem to have elliptical galaxies as host galaxies.
- The interaction with other elliptical and irregular galaxies seem to produce spirals.

Figure 15. Host Galaxies of Quasars (Bahcall and Disney, 1997)

Professor Emily's Pyramid of Distance Indicators



Hubble Constant

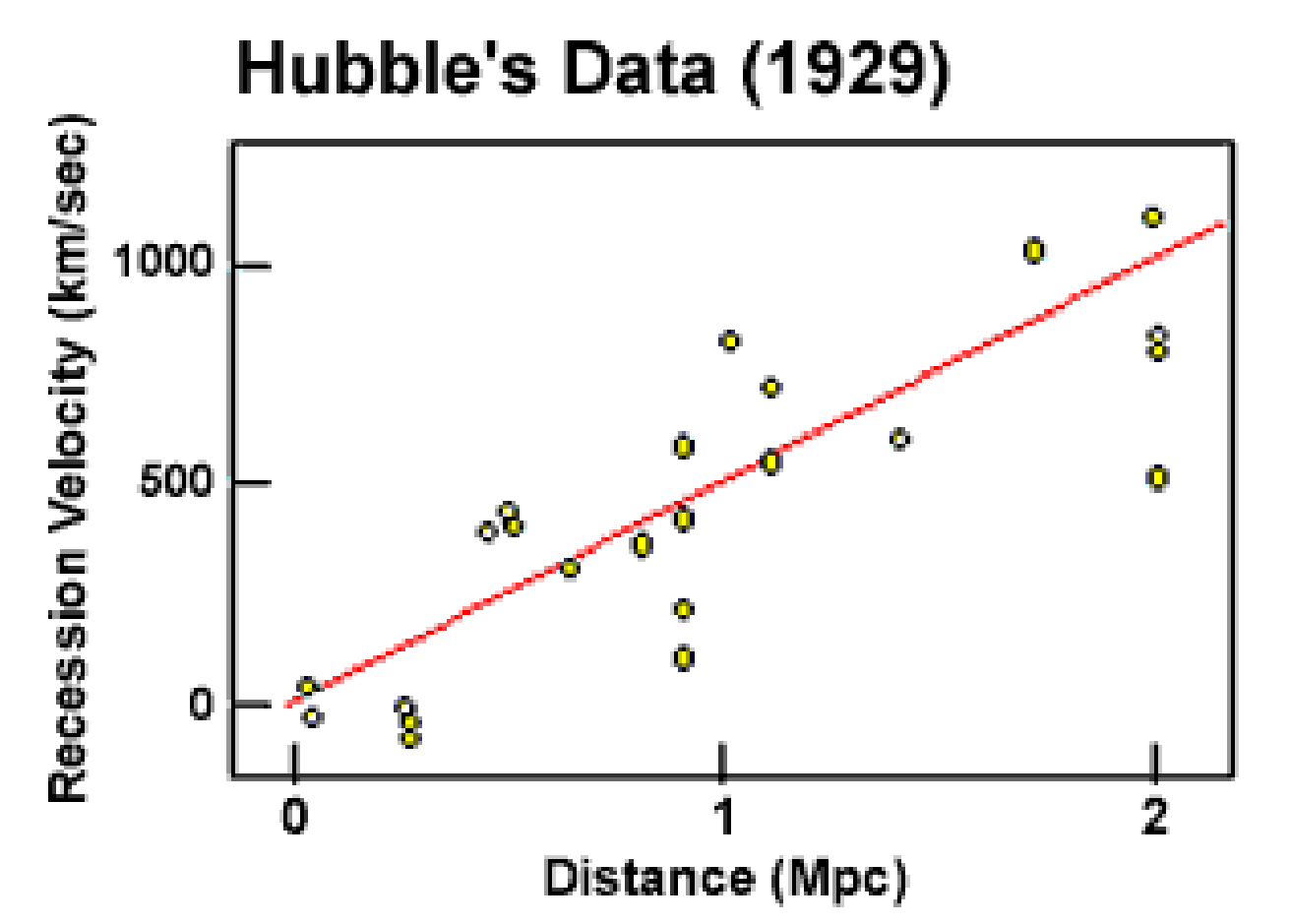


Figure 16. Hubble’s Law (Boyd et al., 2013)

Distance to the Galaxies

- What is the distance to a galaxy that a recessional velocity of 25,000 km/s?

$$Hubble = 72.0\,km/s/Mpc$$

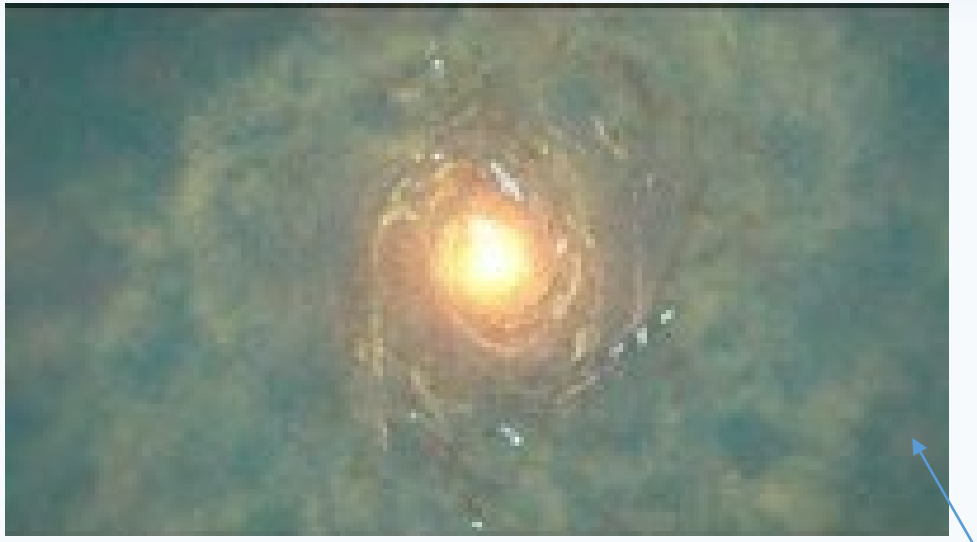
$$\mathbf{Distance} = 25{,}000\,km/s$$

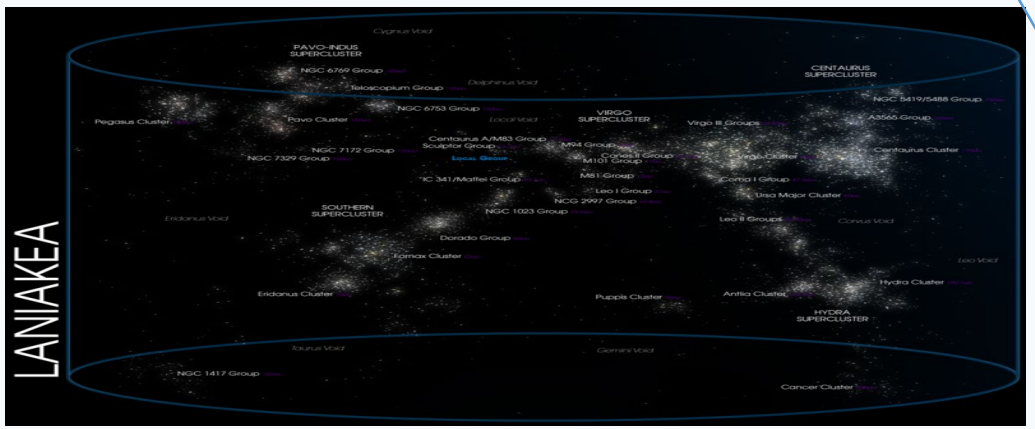
$$d = \frac{v}{H}$$

$$d = \frac{25{,}000\ km/s}{72.0\ km/s/Mpc}$$

$$d = 347\ Mpc$$

Clustering of Galaxies and Galactic Formation





- In the early universe, matter dominated after recombination between matter and anti-matter. The recombination allowed for protons and electrons to build atoms.
- From this matter, the early super stars formed. Supernovae created many black holes which merged to form bigger black holes.
- Galaxies formed around these mergers.
- Many galaxies formed along gravitational eddies creating clusters of galaxies.
- Click to learn about the evolution of a galaxy.

Figures 18. Supercluster of Galaxies (Wiki)

Book/Course References

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