

# Normal Galaxies

**Spiral Nebulae:** what/where are they: inside/outside Milky Way

Observations of the 19th century.

The drawings of Lord Rosse

Edwin Hubble:

1925: Observations of Cepheid variables in Great Nebula in Andromeda (M31)

Period-Luminosity relationship ==> distance of about 1,000,000 light years (Hubble's initial determination)

M31 is a great spiral galaxy very similar to Milky Way

Billions of galaxies observed

Distribution **NOT** smooth: strings and clusters, walls and voids

What are they: **morphology**

**Two major** families

## I. Spirals:

Presence of disk: gas & dust: star formation

Structure of spiral arms:

Structure of central bulge

Sa ==> tight, thin arms; big bulge

Sc ==> loose, massive arms; small bulge

Barred family similar but with central bar through nucleus

Spiral arms usually come off the ends of the bar

## II. Ellipticals

Smooth stellar distribution: No disk: No spiral arms: No gas & dust: No star formation

E0 ==> circular

E7 ==> most oval

## III. Irregular Galaxies: **small fraction** of the total

No symmetry, no arms amorphous structure

Rich in gas & dust: Much star formation

Another set of irregulars highly disturbed; probably interacting systems

Of the **BRIGHT** galaxies:

spirals may represent more than one-half of the observed systems.

What kind of galaxy is the Milky Way?

Spiral arm indicators

Bright O and B stars, ionized hydrogen regions etc.

Local structure in solar neighborhood: parts of spiral arms

Distribution of ISM: atomic and molecular hydrogen: spiral structure

IR information

The Milky Way appears to be a fairly typical barred spiral galaxy probably an SBb

The Stellar Populations

**Population I:** young stellar or pre-stellar material. Gas, dust, O and B stars open star clusters (like Pleiades)

Heavy element content: comparable or richer than that of the sun. Enriched by previous generations of stellar evolution

**Population II:** Old stellar systems. Halo dwarf stars, globular clusters.

Heavy element content: very low compared to sun at 1% or 0.1% level. Formed early in history of galaxy  
**Population I** material dominates the plane of the Milky Way and the disks of spiral galaxies.  
**Population II** material found in luminous halo and central bulges of Milky Way and spiral galaxies.

The **Mass** of galaxies

Galactic Rotation: Kepler's 3rd Law

Newton and Kepler:  $M = \frac{V^2 R}{G}$

Flat Rotation curves

Halos of spiral galaxies

Dark Matter: Mass at least 10 times greater than luminous matter. What is it?

In summary:

What are properties of galaxies:

What are the systematic trends/differences

Stellar properties: Old/young stars: Star formation

Interstellar properties: Presence of gas/dust: Star formation

Structure: disk: arms: bulge: halo

Rotation: Total Mass & Distribution of mass

Are Hubble morphological forms related by evolution:

Is the Hubble tuning fork analogous to the H-R diagram: Most likely No.

How do galaxies form?

I. The old classic: Top down model:

From the largest objects (clusters)

to the smallest (galaxies and stars)

Model explains quite naturally the morphological differences (disk-halo) between Population I and Population II BUT...

If this model is correct how can we explain the young age of the disk of the Milky Way compared to the halo and bulge?

Are we missing something?

The importance of interactions

The Hubble Deep Field

Galaxies at the earliest cosmological epochs

interactions galore

Cluster Density and galaxy types: galactic cannibalism

High density environment favors E galaxies

Low density environment favors S galaxies

Effects of galaxy interactions.

II. Bottom up model:

From the smallest objects (stars and clusters of stars)

to the largest (galaxies and clusters of galaxies)

Galactic cannibalism and effect on structure of galaxies. Is this how the disk of Milky way formed?

Collisions: star bursts: elliptical galaxies

Less dramatic episodes: Gravitational collapse and spiral galaxies

Whichever hypothesis offers the best description of nature, the force of gravity remains supreme.