Plan of Lecture
Galaxies

How are other galaxies similar to and different from the Milky Way?

Types of galaxies.

- **Spiral, elliptical, irregular.**

Measuring properties of galaxies.

- **Distance, brightness, mass.**
- **The Hubble law.**
- **Dark matter.**

Distribution of galaxies.

- **Clusters and voids.**
- **Collisions between galaxies.**

Stellar Populations

We identified several components to the Milky Way.

Nucleus, bulge, disk, halo.

Stellar populations fall into two broad groups.

Disk: high metallicity.

Halo: low metallicity.

Respectively, "Population I" and "Population II".

Gal. center: extreme Pop I.

Why? Stellar evolution makes metals, environment is enriched.

Halo stars (globular clusters) are oldest in Galaxy.

Overview of Galaxies

Galaxies are collections of billions to trillions of stars.

The most massive are 50 times more massive than the Milky Way.

The smallest, dwarf galaxies, are 1000 times less massive.

Distances to galaxies are huge:

Nearest small one: 80,000 lyr.

Nearest big one: 2.2 million lyr.

Galaxies tend to cluster together. Some collections of thousands of galaxies.

This leaves huge voids!

Most of the mass of a galaxy emits little or no visible light.

Types of Galaxies

Galaxies can be loosely grouped into three types:

Spiral.

Disk part; sometimes pinwheel.

Stellar orbits in one direction.

Gas, dust, young/hot stars.

Elliptical.

Round or elliptical (no disk).

Orbits in all directions.

Little gas, dust, hot stars.

Irregular.

Chaotic appearance.

No nuclear bulge or spiral arms.

Faint, small.

Distances to Galaxies

We have often run into the problem of how we measure quantities in astronomy.

For galaxies, this is especially tough because they are so far away.

Distance.

Parallax? Too far away.

Cepheids? Only for close ones.

General idea: calibration. Use known method to prop up another method.

Parallax calibrates Cepheids.

Cepheids calibrate others.

To measure large distances, need things visible over long distances (e.g., supernovae, galaxies).

Distance-Redshift Relation

Early 1900s, astronomers realized that almost all galaxies have redshifts.

Thus, moving away from us.

Galactic bad breath? No! Universe is expanding.

In 1929, Edwin Hubble realized that the redshift is proportional to distance.

This can be used to estimate distances.

More importantly, it shows the universe is dynamic... and had a beginning.

Measuring Mass

Once distance is known, diameter and luminosity are easy. But, mass isn't.

Orbital period and radius give the mass *interior* to the orbit.

Use of Kepler's laws.

Can also total up estimated mass of stars.

But... the two estimates disagree!

Why? Likely because of *dark matter*.

Matter emitting little/no light.

Planets? Black holes or neutron stars? Actually, most has to be even more exotic.

Not made of protons, neutrons!

Major issue in cosmology.

Clustering of Galaxies

Galaxies are social: they tend to group together.

So, distribution is *not* random.

Galaxies as cockroaches.

Where there's one, usually many!

A rich cluster of galaxies has 1000 or more galaxies.

Mostly elliptical.

Cluster diameter $2 - 3 \times 10^6$ parsecs.

Implies: huge voids with very few galaxies.

Can be 10^8 parsecs across!

Near Milky Way, we have a poor cluster: the Local Group.

MW, Andromeda, and debris.

Colliding Galaxies

Stars are far apart compared to their size.

Near Sun, ratio of 10^8!

Stars rarely collide.

But galaxies aren't so far apart.

In cluster, ratio of 10.

Galaxy collisions are expected (and seen).

Individual stars in a galaxy don't collide.

Grav. force between galaxies.

Stellar orbits disturbed.

Gas collides, makes stars.

Larger galaxy "eats" smaller: galactic cannibalism.

Collisions and mergers have major effects.

Summary

Galaxies are giant systems of stars.

Three types: spiral, elliptical, irregular.

Galaxies move away from us.
Distance-redshift (Hubble) relation.

Most of the mass of a galaxy is dark.

Galaxies tend to cluster together.

Challenge: what is the largest globular cluster in our galaxy?