LECTURE 19: GALAXIES AND GALAXY GROUPS

19.1 THE "SIZE" OF A GALAXY

Galaxies have no sharp edges, just a steadily declining density of stars. On a deeper photograph (longer exposure), a galaxy looks bigger.

A well-defined "size" is the half-light radius R_h, the radius that encloses half of the galaxy's light.

A galaxy's "optical extent" on a typical astronomical photograph is about $3R_h$.

Radio telescopes detect hydrogen gas clouds out to $\sim 10R_h$ in many spiral galaxies.

The extent of dark coronas is unknown. Tentative evidence suggests that they continue out to $\sim 50R_h$.

19.2 A SKETCH OF THE MILKY WAY

The Milky Way is a fairly typical bright spiral galaxy (as is Andromeda).

Disk: Population I stars, open clusters, gas clouds, spiral arms
  luminosity: 15 billion $L_\odot$
  mass: 60 billion $M_\odot$
  half-light radius: 6 kpc
  solar radius: 8 kpc
  rotation speed: 220 km/s

Spheroid: Population II stars, globular clusters
  luminosity: 2 billion $L_\odot$
  mass: 20 billion $M_\odot$
  half-light radius: 2 kpc

Dark matter corona: composition unknown
  size: poorly known, probably 100-400 kpc
  total mass: poorly known, probably about 1 trillion $M_\odot$

19.3 TYPES OF SPIRAL GALAXIES

Spiral galaxies have a range of visual appearance.

Hubble's classification:

Sa – prominent spheroid, tightly wound spiral arms, little gas

Sc – almost no spheroid, loosely wound arms, lots of gas

Sb – intermediate

The Milky Way is probably an Sb galaxy.

There is a parallel sequence of barred spirals.

19.4 ELLIPTICAL GALAXIES

Elliptical galaxies have a spheroid but no disk.

Their observed shapes range from round to a flattening of about 3:1.

They rotate slowly (compared to spirals) because their stars are not all orbiting in the same direction.

Most ellipticals are pure Population II: only old stars, little gas or dust, and no ongoing star formation.

19.5 IRREGULAR GALAXIES

Irregular galaxies have an amorphous appearance.

They are pure Population I: young and old stars, lots of gas and dust, lots of star formation.

They are less luminous than bright ellipticals and spirals.

An irregular galaxy has some resemblance to a "chunk" of a spiral arm.

Andromeda is the closest *bright spiral* galaxy to the Milky Way. Its distance is 700 kpc.

The Magellanic Clouds, two irregular galaxies, are much closer to the Milky Way. Their distance is 50 kpc.

19.6 GALAXY LUMINOSITIES

Galaxies have a wide range of luminosities, and it is hard to define a "typical" value.

The most luminous galaxies are $\sim$ 100 billion $L_\odot$, about 5 times more luminous than the Milky Way.

The least luminous galaxies are $\sim$ 10 million $L_\odot$, about 1000 times less luminous than the Milky Way.

There are many more faint galaxies than bright galaxies. However, most stars are in galaxies that are roughly as luminous as the Milky Way.

19.7 GALAXY GROUPS

Most galaxies reside in groups.

These range from a few galaxies (small group) to a thousand or more galaxies (rich cluster). The typical size is about 1000 kpc.

The Milky Way, Andromeda, and about 20 small galaxies (including the Magellanic Clouds) make up the *Local Group*.

The motions of galaxies in groups imply that more mass is present than is seen in visible stars (or else there wouldn't be enough gravity to stop the group from flying apart). These motions provide more evidence for dark matter.

Groups and clusters are themselves arranged in enormous sheets and filaments, called superclusters.

19.8 SUMMARY

The Milky Way is a "typical" spiral galaxy, to the extent that there is such a thing.

As we follow the sequence of galaxy types
Elliptical $\rightarrow$ Sa $\rightarrow$ Sb $\rightarrow$ Sc $\rightarrow$ Irregular
we also follow a sequence
spheroid dominated $\rightarrow$ disk dominated $\rightarrow$ amorphous
Population II $\rightarrow$ Population I
Old stars $\rightarrow$ young stars
No gas and dust $\rightarrow$ lots of gas and dust
no star formation $\rightarrow$ vigorous star formation

Galaxy luminosities range from 1/1000 the Milky Way to $5\times$ the Milky Way.

Most galaxies live in groups or clusters.