# GALAXIES & THE MILKY WAY

GALAXIES

- Galaxies are huge collections of stars: millions to trillions of stars ($10^6$ - $10^{13}$); 100 billion is common ($10^{11}$)
- Size: $10^4$ - $10^7$ lt-yrs across; 100,000 lt-yr is common.
- Some contain a lot of gas and dust (nebula)
- Mostly empty space - stars almost never collide – the distances are too enormous

Three types of galaxies:
ELLIPTICAL
SPIRAL
IRREGULAR

Structure of Elliptical Galaxies

- Elliptical galaxies contain almost no dust or gas.
- All the stars are old.
- Spheroidal shaped.
- Stars move on random orbits; no net rotation.

Structure of Spiral Galaxies

The Andromeda galaxy, 2.5 million light years away, is a good example of a spiral galaxy.

- **Nucleus:** central region
- **Bulge:** slightly flattened sphere around the center; very little gas or dust; high density of stars on random orbits.
- **Disk:** flat; contains the spiral arms; lots of gas & dust. In the disk, the stars orbit in nearly circular orbits. The tightness of the spiral arms can vary from galaxy to galaxy.
- **Halo:** surrounds the galaxy; stars on random orbits; no dust or gas; most stars are in globular clusters

*Globular clusters* are large, old, spherical star clusters that orbit the galaxy out in the halo. They contain roughly one hundred thousand to a million stars and no gas or dust, and are ~ 50 pc in size. They are typically older than 10 billion years, and with no star formation going on, they have no young stars. They are metal-poor stars, meaning they are deficient in elements heavier than helium. There are about 150 globular clusters around the Milky Way. Larger galaxies may contain thousands of globular clusters. [Notes: Globular clusters are very different from "open" or "galactic" clusters.]

Some spirals have a "bar": a linear band of stars across the central region of the galaxy.

Rotation of Spiral Galaxies.

Spiral galaxies rotate: most stars in the disk are moving in the same direction and on nearly circular orbits. We can use this to estimate the mass of the galaxy.

Star formation occurs only in the disk, mainly in the spiral arms.
Why?
This is the only place where there is enough gas and dust (cold nebula)

*Spiral arms* are not solid material - they are compression waves: slightly over-dense regions of the disk.
Compression of the dust & gas triggers star formation: the compression causes protostellar nebulae to collapse into stars.
High-luminosity, short-lived O & B stars exist only in the spiral arms. This is why the arms are so bright.

<u>The Milky Way Galaxy</u>
The "Milky Way" is our home galaxy. It is a spiral ~ 100,000 lt-yr across.
Sun is in the disk, about 28,000 light-years from the nucleus; no place special.

<u>Irregular Galaxies</u>
Irregular galaxies are messy-looking galaxies. They are often the result of galaxy collisions & mergers. The collision will often trigger new bursts of star formation, so irregular galaxies are often blue in color.

Ellipticals may be formed from collisions of many galaxies.

Our own galaxy has merged with other smaller galaxies in the past.

<u>Quasars & Active Galactic Nuclei (AGN)</u>
The nuclei of some galaxies are *extremely* luminous: brighter than the rest of the galaxy combined ( > billions of stars).
Sometimes all you see is the active nucleus; the galaxy is drowned out
A ***quasar*** is an AGN that produces a lot of radio emission and whose galaxy can't be seen.

Light from an AGN is:

- rapidly variable
- contains both high-energy (X-rays) *and* low-energy (radio) photons; therefore cannot be from stars
- comes from a very small region ( <1 lt-yr across)

Thermonuclear fusion cannot provide enough energy to power an AGN. So what powers an AGN? →Accretion onto a *supermassive* black hole!
The black hole must be millions to billions times more massive than the Sun.

<u>Supermassive BHs in Normal Galaxies</u>
Based on the orbits of stars in their nucleus, almost every galaxy has a supermassive black hole in its center.
These are not AGN because they are not accreting - there's no gas around them to swallow; these may be "dormant AGN".

Our Milky Way has a supermassive BH too: *"Sag A*"* (pronounced "Sagittarius A-star").
The galactic nucleus has been studied using radio, infrared, and X-ray light – these are able to pass through interstellar dust. A strong radio source called Sagittarius A* is located at the galactic center. This marks the position of a supermassive black hole with a mass of about $3.7 \times 10^6\ M_\odot$.
As expected, the gravity from the supermassive black hole is just normal gravity once we are far from the event horizon. So the black hole does not "suck in" the galaxy.