More on the Milky Way

Parts of the Milky Way

- Disk
  - Stars, gas, and dust
  - Young & old stars
  - Motion is circular
- Bulge
  - Stars are dense
  - Motion is elliptical in all directions
- Halo
  - Stars are sparse; dark matter
  - No young stars
  - Spherical in shape
  - Motion is elliptical in all directions
- Globular clusters
- Disk stars move in a circle around the center of the Milky Way. Orbits dip above and below the plane of the disk.
- Halo and bulge stars move in long, skinny orbits in all directions.
Edge-On View

Face-On View
Mass within Sun’s orbit:
$$1.0 \times 10^{11} \text{ } M_{\text{Sun}}$$

Total mass:
$$\sim 10^{12} \text{ } M_{\text{Sun}}$$

**Dark Matter**

- The gravitational mass of the Milky Way seems to be much larger than the mass of all of the gas, stars, and dust that we can see!

- Nobody knows what the “dark matter” is
How did our galaxy form?

Our galaxy is thought to have formed from a giant gas cloud.
Halo stars formed first as gravity caused cloud to contract.

Gas left over from halo formation settled into spinning disk.
Stars continuously form in disk as galaxy grows older

Warning: This model is oversimplified

Stars continuously form in disk as galaxy grows older
Detailed studies: Halo stars formed in clumps that later merged

Clicker Question

We think that there is "dark matter" in the Galaxy because
A. Stars in the outer part of the Milky Way move slower than expected
B. Stars in the outer part of the Milky Way move faster than expected
Fig 19.2

Gas and dust from stars: Stellar Winds, Planetary Nebulae, Supernovae
Gas and dust from stars: Stellar Winds, Planetary Nebulae, Supernovae

Tycho supernova
X-ray image
Gas and dust from stars: Stellar Winds, Planetary Nebulae, Supernovae

Cas A supernova X-ray Image

Clustered Supernovae make Superbubbles

View of the Large Magellanic Cloud

hot, ionized gas
Molecular Clouds

Doppler shifts of CO clouds in Orion

300 light years across
Dark Cloud: on the brink of collapse

12,500 AU across, 16K

A black hole at the center?
Milky Way’s Central Black Hole

Mass around 4 million solar masses

Are there other galaxies?

• Up until 1925 there was debate on this
1925 Edwin Hubble

- Discovers Cepheids in the Andromeda Nebula
- Uses the Cepheid period-luminosity relation to determine the distance to the Andromeda Nebula
- Proves that it is an external galaxy

Andromeda Galaxy

About 2 million light years away
How far can you see with the naked eye?

- On autumn evenings, from a dark site, you can see the Andromeda galaxy with the naked eye.

The Local Group
Clicker Question

About how big is the Milky Way from edge to edge?
A. 4 light years
B. 100 light years
C. 100,000 light years
D. 1,000,000,000 light years

Other Galaxies
Other Galaxies

Elliptical Barred Spiral Irregular Spiral

M87

Hubble Ultra Deep Field