Chapter 15: The Milky Way Galaxy

A. It was once believed (prior to the 1920s) that the Milky Way was the entire universe.

1. Spiral Nebulae observed by earlier astronomers (ex. Lord Rosse) were believed to be part of the Milky Way and thought to be evidence for the nebular hypothesis.

2. Shapley-Curtis Debate: Did not reach any conclusion due to lack of evidence from both sides.

Shapley: Argued that spiral nebulae were just nearby gas clouds and that the Universe was composed of just one big Galaxy. The Sun was far from the center of this Great Galaxy.

Curtis: Argued that the Universe was composed of many galaxies like our own. He placed the Sun at the center of a much smaller Galaxy.

Why is the debate important?

"The Shapley-Curtis debate makes interesting reading even today. It is important, not only as a historical document, but also as a glimpse into the reasoning processes of eminent scientists engaged in a great controversy for which the evidence on both sides is fragmentary and partly faulty. This debate illustrates forcefully how tricky it is to pick one's way through the treacherous ground that characterizes research at the frontiers of science."

Shu, F., 1982, "The Physical Universe, An Introduction to Astronomy"

3. Edwin Hubble: Observed Cepheid variables in M31 and showed that it was outside of the Milky Way. Applied the Period-Luminosity Law that had been discovered by Henrietta Leavitt in 1912.

4. Cepheids have been observed in more distant galaxies, such as M100 in the Virgo cluster.

B. Milky Way Galaxy: our home galaxy.

C. Early views of galactic structure.

1. Herschel's star counts (nineteenth century):

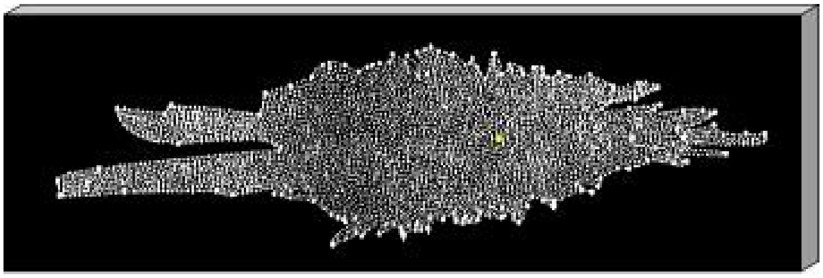

Figure 1

Lozenge shaped. Did not have knowledge of stellar distances or interstellar extinction. Sun at center.

2. Harlow Shapley (1917) determined true nature of our galaxy by determining distances and distributions of globular clusters using RR Lyrae variables. Found that globular clusters were centered around a region in the constellation Sagittarius.

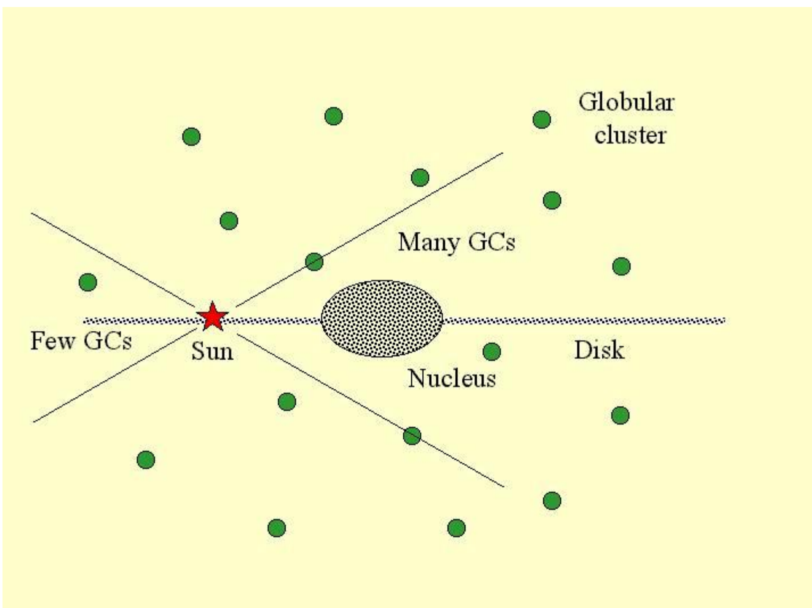

Figure 2

D. Milky Way Structure:

1. Disk:

a. 100,000 ly wide and 15,000 ly thick. Contains population I and population II stars, gas and dust.

i. Within the disk there is some evidence stars above and below the center of the disk get older the farther one goes from the center.

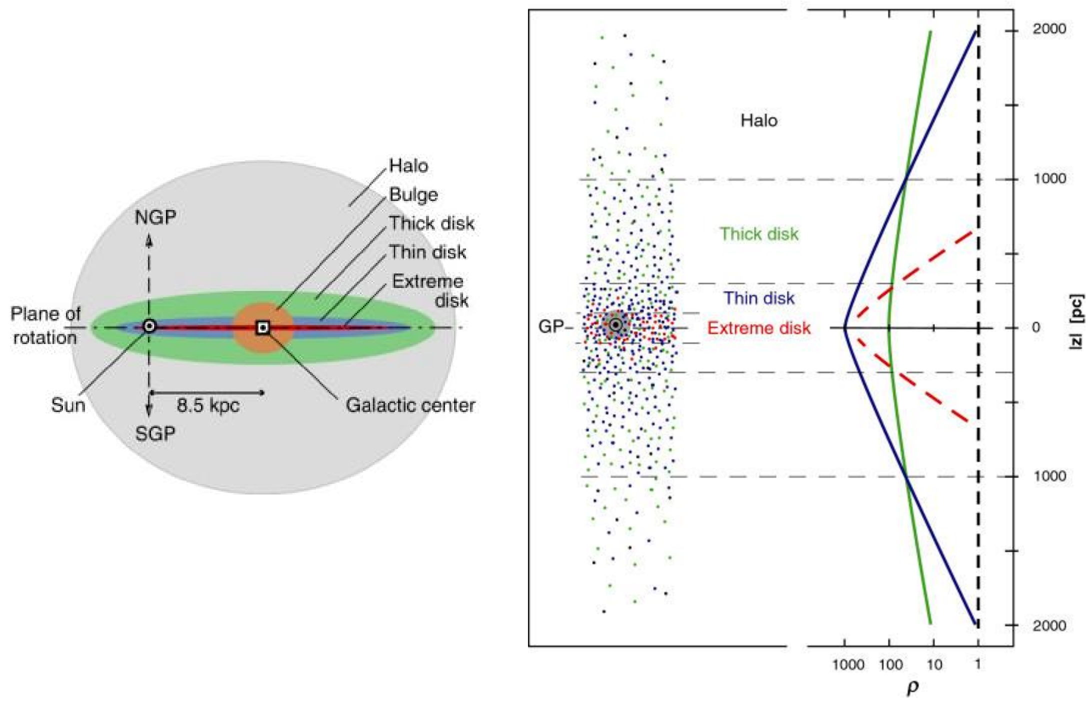

Figure 3

b. Spiral arms:

i. Young blue stars (population I).

ii. Dust and gas.

1. Dust detected by polarization of star light, reflection

nebulae, dark nebulae, and thermal radiation (IR emission).

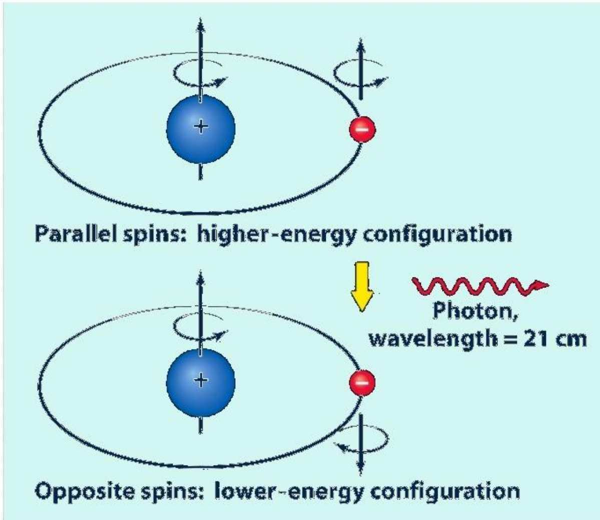

Figure 4

2. Gas detected by H II regions, 21-cm radiation.

iii. Spiral Tracers: Dust limits visual observations to about 10,000 ly.

1. H II regions.

2. OB associations.

3. Carbon monoxide emissions from molecular clouds.

4. Emissions by 21-cm radiation of neutral hydrogen.

5. Open clusters.

6. Dark nebulae.

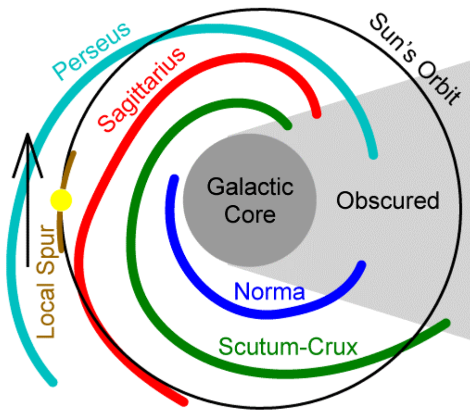

Figure 5: Spiral Arms

iv. Distances indicators:

1. Cepheid variables. Luminosity is directly proportional to the period of pulsation.

2. RR Lyrae stars. All RR Lyrae stars have the same luminosity, since they are found on the horizontal giant branch.

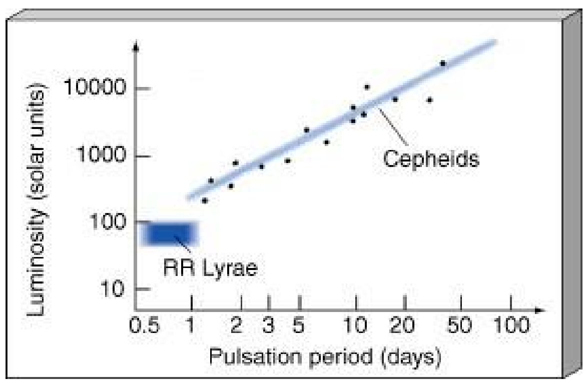

Figure 6

Concept Test

Choose the best evidence that the disk of the Milky Way Galaxy does NOT rotate like a solid wheel.

a) Disk stars have Doppler shifts.
b) The brightest disk stars form spiral shapes.
c) Disk stars rotate twice as quickly that are twice as far from the Galactice center.
d) The rotation of disk stars around the Sun decreases with distanceaccording to Kepler's laws.

2. Halo:

a. Old stars (population II).

b. Globular star clusters.

c. Halo retains the spherical shape that the galaxy had prior to its collapse. The stars within the halo have random orbits that reflect the original motions.

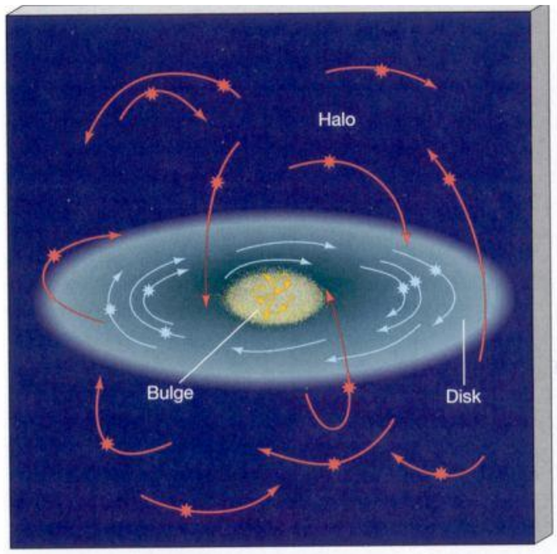

Figure 23.13 Stellar Orbits in Our Galaxy Stars in the Galactic disk move in orderly, circular orbits about the Galactic center. In contrast, halo stars have orbits with largely random orientations and eccentricities. The orbit of a typical halo star takes it high above the Galactic disk, then down through the disk plane, then out the other side and far below the disk. The orbital properties of bulge stars are intermediate between those of disk stars and those of halo stars.

Figure 7

3. Nuclear bulge: About 20,000 ly wide. Consists of young and old stars (population I & II), gas and dust.

4. Galactic Nucleus: Center of the nucleus in the direction of Sagittarius.

a. Strong radio source producing synchrotron radiation.

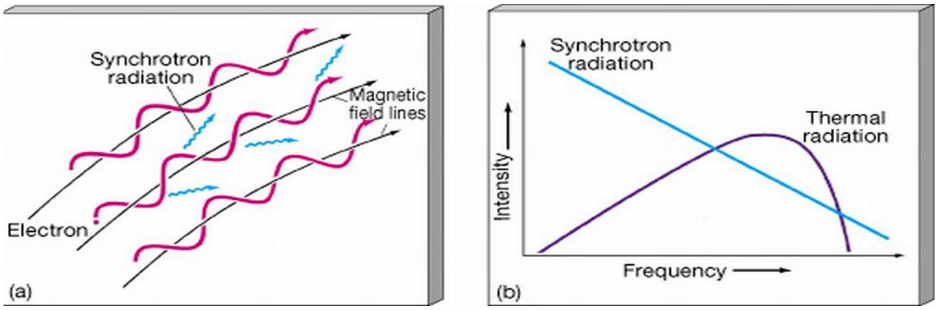

Figure 8
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b. Motions in the nucleus indicate a mass of 2,500,000 solar masses, which has been interpreted as a supermassive black hole.

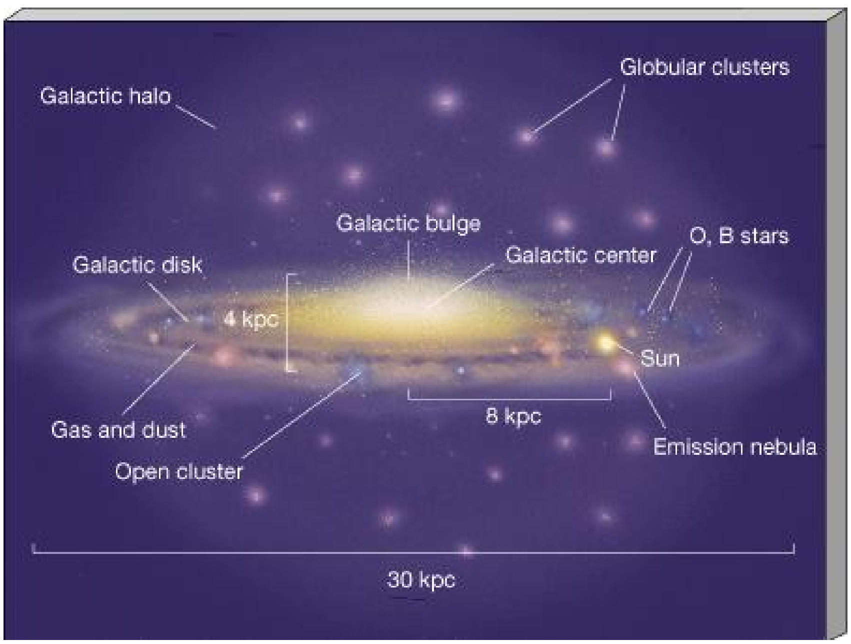

Figure 9
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E. Mass of the Galaxy.

1. Mass is determined by applying Kepler's 3rd law to the motions of stars about the galactic center.

2. Complication: not all of the Galaxy's mass is concentrated at the center. Instead it is spread throughout the disk.

a. Period of Sun depends on the mass within its orbit.

i. Orbital velocity of Sun is 220 km/s.

ii. Orbital period of Sun is 225 million years.

3. Mass of the Galaxy within the Sun's orbit is about 100 billion solar masses. About 1/2 of this is stars.

4. Mass outside the Sun's orbit.

a. Halo stars.

i. Old stars with randomly oriented orbits.

b. Dark Matter.

i. Invisible at all wavelengths.

ii. Presence is revealed by the rotation curve of the Galaxy.

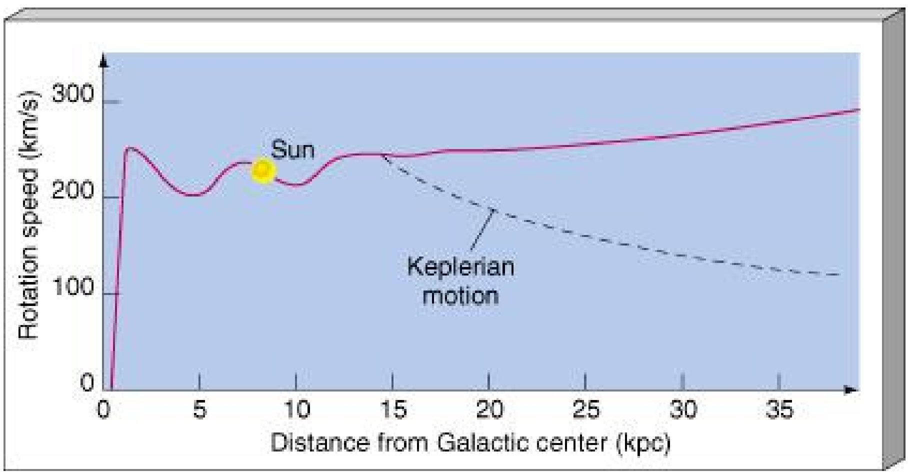

Figure 10
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c. Total mass from the rotation curve is about 600 billion solar masses and could be larger.

d. Possible sources of the dark matter:

i. Brown dwarfs.

1. Microlensing: When a brown dwarf passes in front of a distant star the bending of light by gravity causes the distant star to brighten. This technique has been used to detect brown dwarfs in the Milky Way's halo.

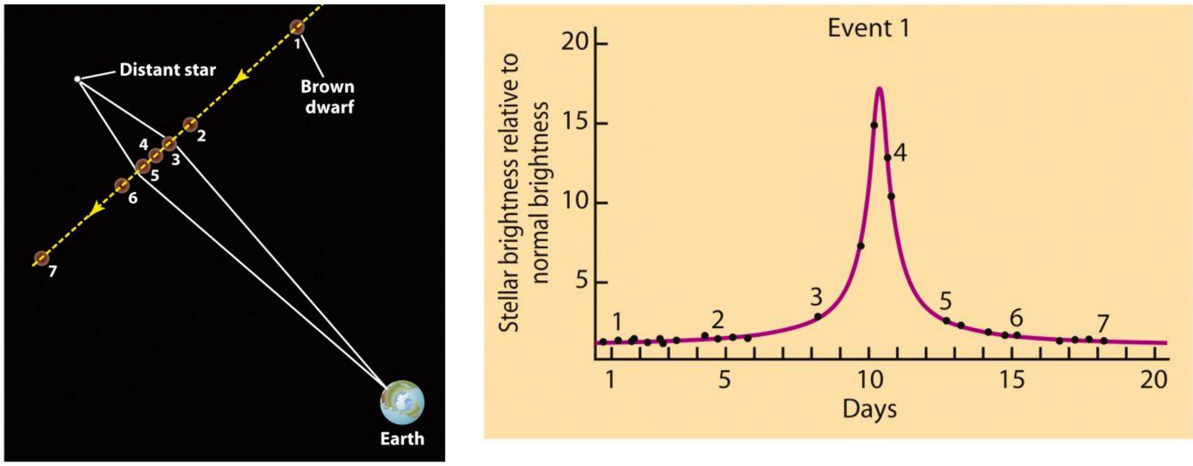

Figure 11

ii. White dwarfs.

iii. Low mass red dwarfs.

iv. Undetected subatomic particles (WIMPS).

F. Recent Developments

1. Milky Way Galaxy appears to be a barred spiral.

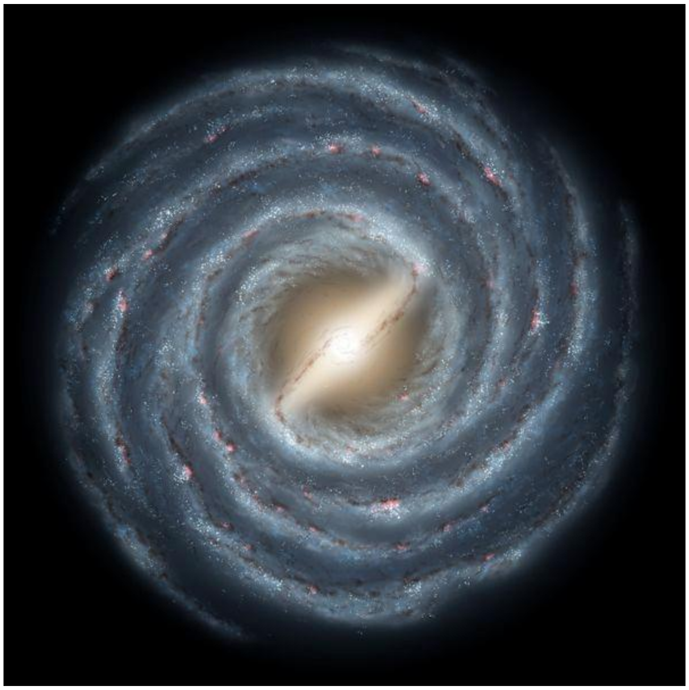

Figure 12: Artist's conception of the Milky Way Galaxy

2. Milky Way's disk is warped due to interactions with the Magellanic Clouds.

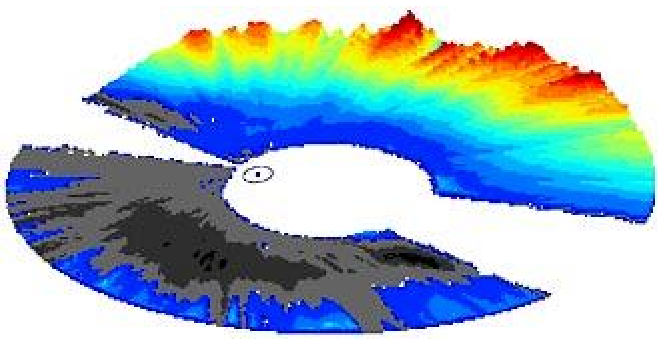

Figure 13

3. Cannibalism: Milky Way is currently devouring a dwarf galaxy called the Sagittarius dwarf.

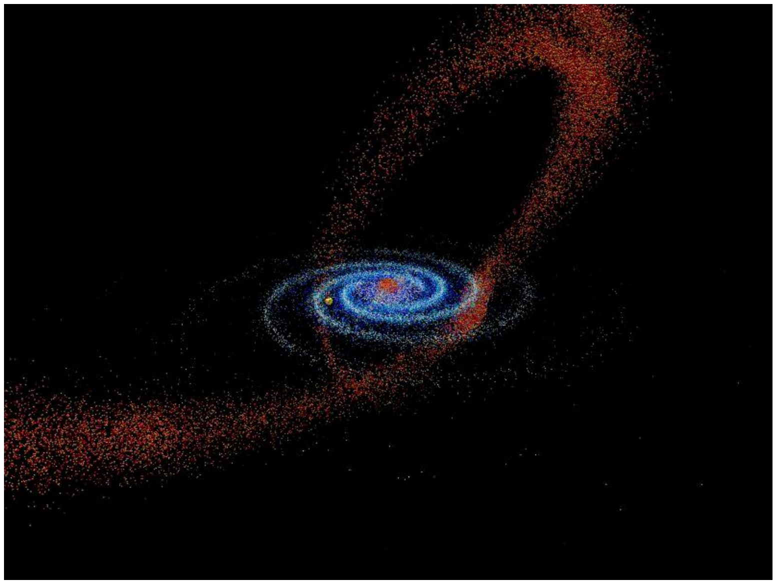

Figure 14: Shredded Sagittarius Dwarf