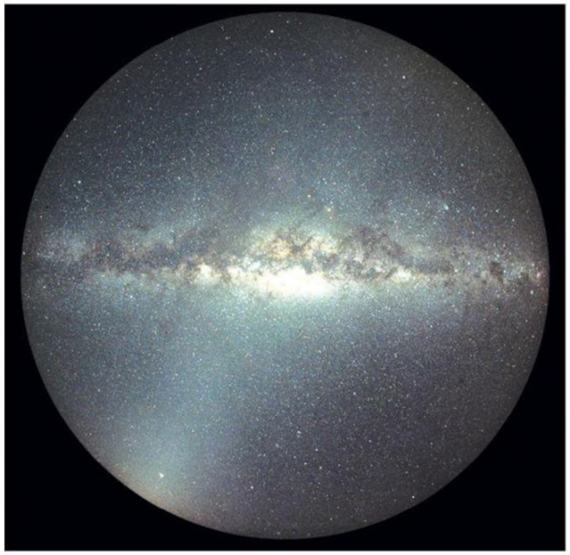
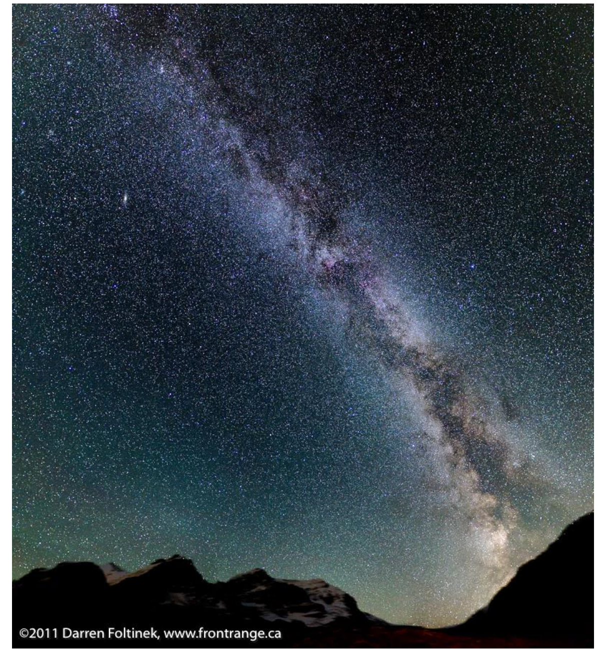
The Milky Way - Chapter 22





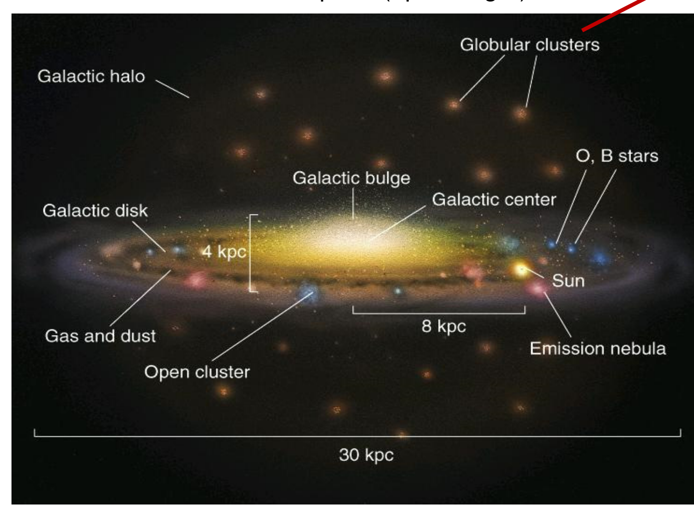
Best seen around August, running NE to SW

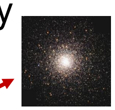
The Milky Way Galaxy

- A galaxy: huge collection of stars (few 100 up to ~ 10^{14}!), interstellar matter (gas & dust), and dark matter, held together by gravity. But there is no accepted formal definition of a galaxy!
- Our galaxy: *the Galaxy*, or *the Milky Way.*

Take a Giant Step Outside the Milky Way

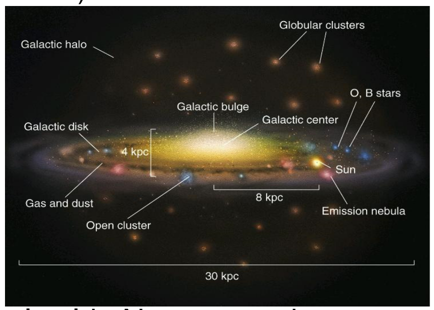
Artist's Conception (optical light)





Example (not to scale)

- Disk: young and old stars, gas and dust, ongoing star formation. Stars have relatively high "metal" content because most formed out of ISM "enriched" by fusion in previous generations of stars ("Population I" stars). This is where most stars are (~1-4 x 10^{11}).

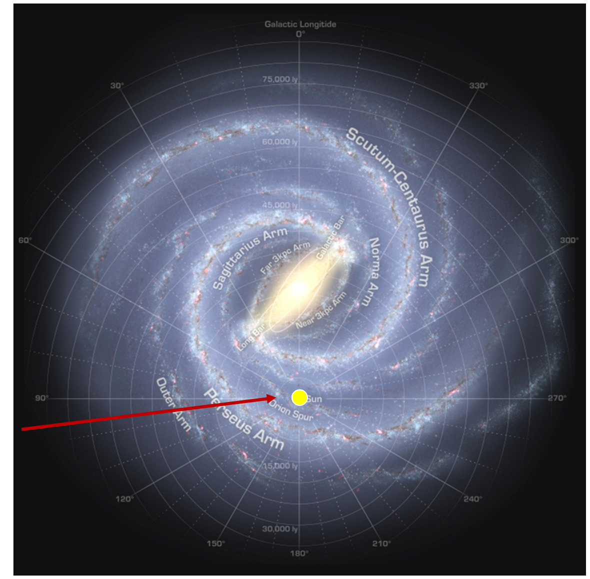


- Halo: oldest stars (13 Gyr or so). Globular clusters account for 1% of halo stars. Low metal content ("Population II" stars). Only several billion stars. Little gas.

- Bulge: several billion stars – mostly old. Not as prominent as shown. More like 1 kpc across and 600 pc vertical extent.

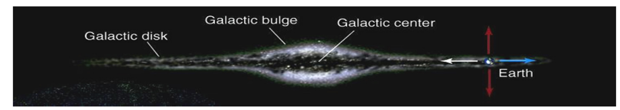
- (not shown: dark matter, also in a quasi-spherical halo form, larger than stellar halo).

From above (face-on) see disk, which features spiral structure and a bar, and bulge (halo too faint)



Sun

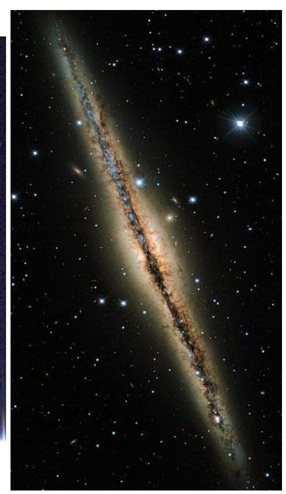
From the side (edge-on)



Galaxies roughly resembling the Milky Way

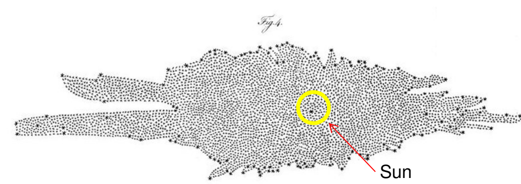
Messier 109

NGC 891



Historical measurements of the size and shape of Milky Way

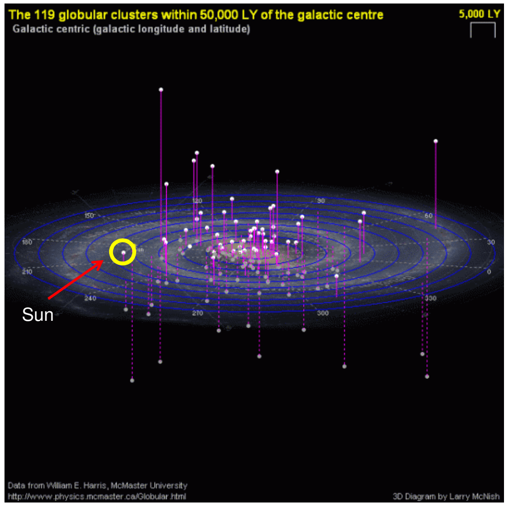
- First attempts by Caroline & William Herschel (1785) and Kapteyn (1922) by counting stars through telescopes.
- Both found MW is a flattened structure. But both put the Sun near the center. Studies limited by small telescopes, lack of understanding of extinction by dust, and (in Herschels' case) no stellar distances had been determined. Kapteyn inferred MW only 17 kpc across.
- This was before spiral structure known, or that some "nebulae" were galaxies beyond MW.



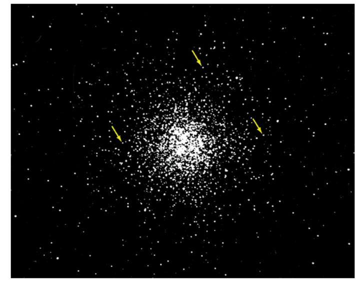
Herschel's drawing of the Milky Way (side view)

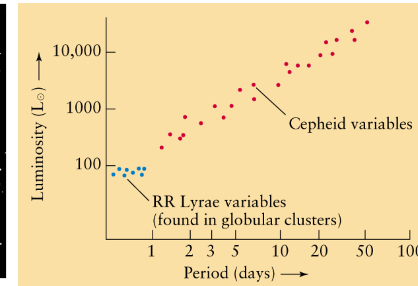
Shapley – Globular Clusters

- Shapley (1915-21) used globular clusters:
  - Uniformly distributed above & below the MW plane.
  - He found they had large distances (next slide).
  - Assumed they formed a system centered on center of MW.
  - Noted a concentration toward Sagittarius. Inferred center was in that direction.



- Shapley used RR Lyrae variable stars in globular clusters to determine their distances and thus size of the MW and our distance from center.
- RR Lyraes:
  - Easy to spot, and all have same luminosity
  - Periods of several hours
  - Evolved low mass (HB) stars, thus older than Cepheids

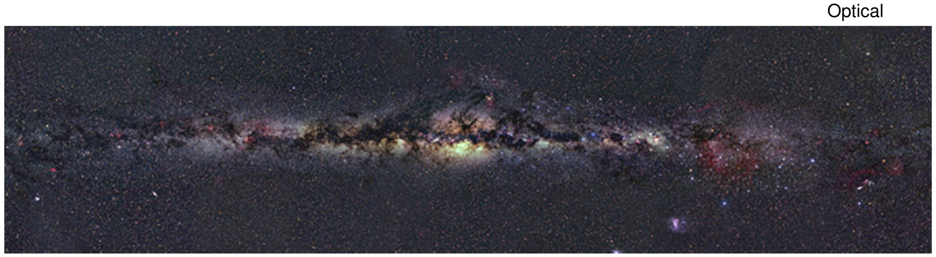




- Still no dust correction!
- Found Sun 16 kpc from center. Modern value 8 kpc.

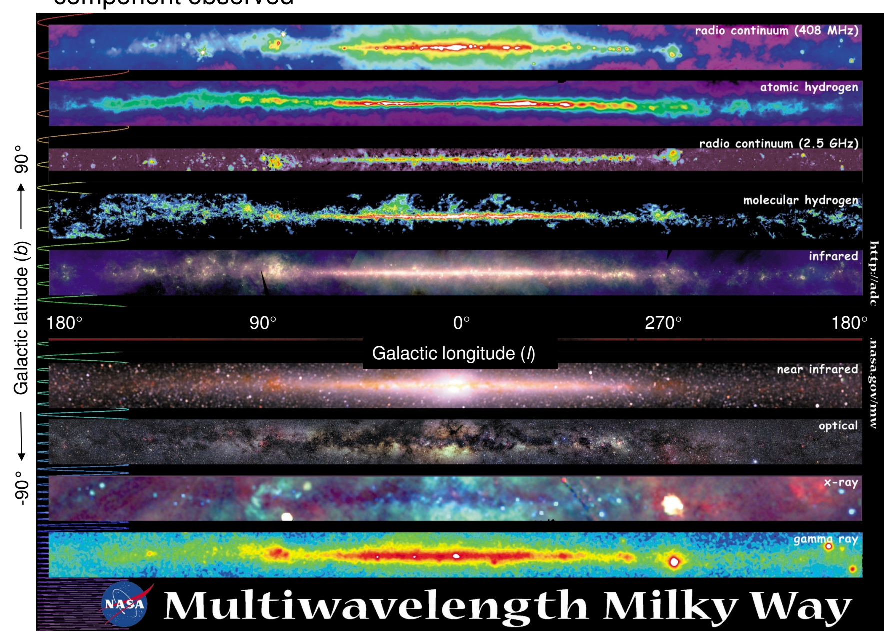
Nowadays use near-IR imaging to better probe stellar structure of MW. Near-IR penetrates dust better, reveals true stellar distribution better, including disk, bar and central bulge.

Optical

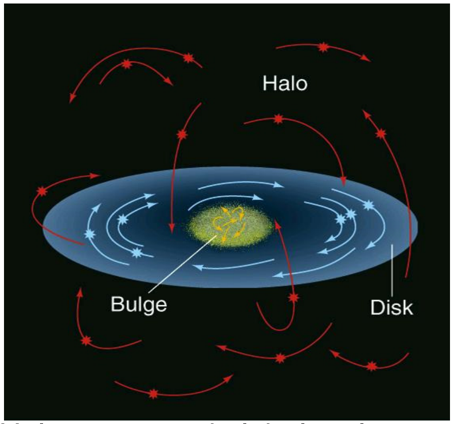


2 micron (2MASS survey)

Milky Way appears very different depending on wavelength or physical component observed



Orbits



Halo: stars and globular clusters swarm around center of Milky Way. Very elliptical orbits with random orientations.

Bulge: similar to halo.

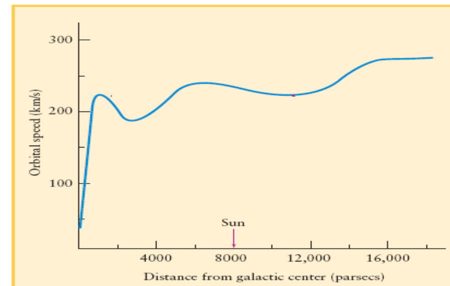
Disk: stars, gas, dust rotate.

Rotation of the Disk

Sun's rotation speed 225 km/sec. An orbit takes 240 million years. Objects with known distances at other radii, and measured Doppler Shifts, used to define "rotation curve".

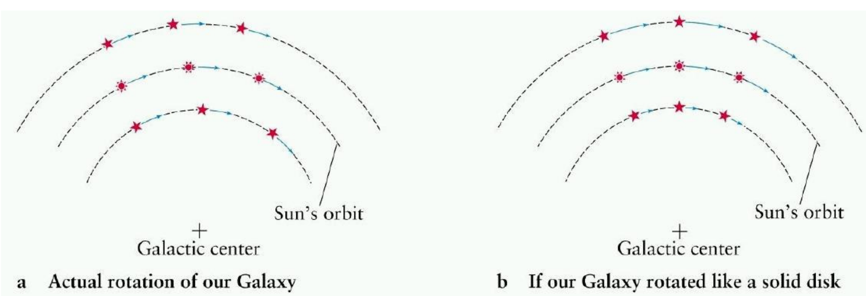
Orbital period increases with radius => rotation not rigid. Rather, "differential rotation".

Over most of disk, rotation velocity is roughly constant.



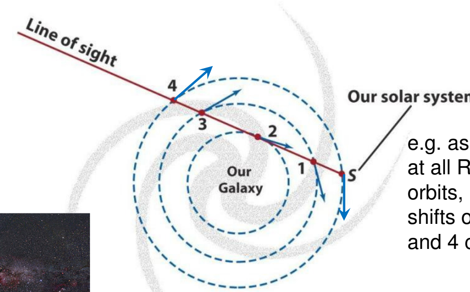
The rotation curve of the Milky Way

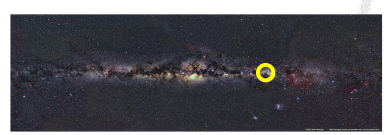
If V=const, how does period depend on R?



Once rotation curve known, can use it to measure distances to other objects in disk ("kinematic distances") => determine distribution of various components, e.g.:

- Stars, from Doppler shifts of stellar absorption lines.
- Ionized gas, via emission lines from HII regions.
- Atomic gas, via the 21-cm line.
- Molecular gas, via lines of CO and other molecules





e.g. assume V=const at all R, and circular orbits, how will Doppler shifts of stars at 1, 2, 3 and 4 compare?