Milky Way Galaxy

- Milky Way – spiral galaxy - flattened disk 150,000 LY in diameter with about 400 billion stars
- we sit in a gas/dust “arm”
  - active star formation
  - absorbs visible light
- study using IR/radio/gamma or by looking at other galaxies
Milky Way Structure

- Nucleus
- Disk
- Halo
- Sun is about 30,000 LY from center and is in one of the spiral arms
Galaxy Nucleus

- In direction of Sagittarius. Nucleus: high density of stars, 10 million within radius of about 4 light years. Many are old but “bursts” of new stars a few million years ago and maybe another burst in 200 million years?? (evidence isn’t clear)

- Very active star formation in past → many supernova remnants and many black holes with super massive BH at center >1,000,000 Mass(Sun)
Galaxy Nucleus

- Study mostly using radio and IR part of spectrum, SNR=supernova remnant
SO-1 through SO-102 are different objects in the galactic center measure motion over time (20 years). All clearly orbiting a common center → get mass in center (like Kepler) indicating something very massive.
Galactic Center → many black holes

NASA Chandra X-ray telescope

12 sources in cyan circles have black hole-binary (a regular star plus a black hole) spectrum. The yellow circle has a radius of 3 light years around the supermassive black hole at the galactic center.

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Milky Way Galaxy - Disk and Halo Stars

- **In Disk**
  - lots of bright, young stars
  - lots of gas and dust
  - stars abundant in heavy elements (young Type I) → earlier generations formed heavy elements
- **active star formation**
- **in Halo**
  - mostly old red stars
  - no gas/dust
  - no heavy elements (just H and He) (old Type II stars)
- **no current star formation**
Globular Clusters → Halo Stars

Groups of old red stars (only H and He) outside plane of galaxy. “fossil” remnant of shape of early galaxy

M10: 85 LY across, 16,000 LY from Earth
Size and Shape of Galaxy

- measure distances to globular clusters
- outside plane of galaxy → not obscured by gas and dust (done early in 20th century). Only have limited range near us where we can “see into” Milky Way in visible
- tell where center of galaxy is, not uniformly distributed about our Sun
- Gives shape of early Galaxy
Galaxy Disk

- we are located about 30,000 LY from galaxy center
- region which has an abundant amount of gas/dust and active star formation
- earlier generations of stars formed heavy elements with supernovas and giants throwing these into the mix → new generation of stars (like ours) have C, O, Fe, etc
Radio Maps of Galaxy

• Cold gas (H, H$_2$, He, C), water…) emits and absorbs in Radio

• most important: 21 cm atomic H. spin (magnetic field) flip like in MRIs (Magnetic Resonance Imaging)

• Gives
  
  - relative abundance of gas in different regions
  - velocities of gas clouds (from Doppler shift)

• used to determine shape/mass of galaxy, pattern of spiral arms
21 cm line in H (like MRI) – Doppler Shifts

Radio maps. Different peaks are at different velocities and show different arms. Research done by former NIU student Ed Mierkiewicz while at Wisconsin. Now professor at Embry-Riddle Aeronautical University in Florida
Radio Maps of Galaxy

use Doppler shift to get velocity of different regions, identify different arms
Galaxy Formation

- Rotating gas cloud about 13 billion years ago
  - local concentrations give first stars
- Cloud collapses due to gravity
  large rotation $\rightarrow$ spiral
  small rotation $\rightarrow$ elliptical
  near other big galaxy $\rightarrow$ irregular
- Often interacting with other galaxies
- Gas/Dust/Star formation persist in spiral and irregular
Milky Way Formation

old stars in halo give shape early in formation
Elliptical vs Spiral Galaxy Formation

if less initial rotation easier for early star formation prior to collapse into disk ➔
ellipticals have more stars at beginning, spirals more later

Sequence of events ➔

a  Formation of a disk galaxy

b  Formation of an elliptical galaxy
Elliptical vs Spiral Galaxy Formation

Elliptical galaxies tend to have older stars. Lots of blackholes in early stage. Newer telescopes able to study stars which are >5 billion light years away and so at an earlier time of Universe and earlier in the formation of galaxies.
Colliding and Merging Galaxies

galaxies pull on each other by gravity

→ orbits

→ interact

→ can merge

happens over billions of years

Andromeda and Milky Way will collide/merge in about 4 billion years. In video linked to our web page
In Milky Way stars move around center

Most stars in the disk move in the same direction as part of the original Milky Way. But some move in the opposite way (clockwise vs counter-clockwise in this picture) as they were originally in another galaxy which merged with the Milky Way.
smaller galaxies often consumed by the larger galaxy. The Milky Way is probably doing this to its nearby dwarf galaxies.
Lecture Feedback

E-mail me a few sentences describing one topic you learned from this set of presentations. Please include the phrase “Spiral galaxies like the Milky Way have active star formation in the spiral arms” in your mini-report but do not use that as your “one topic”.


Extra Slides
Spiral Arm Formation

where stars are being formed in spiral arms “moves” over time as gas/dust is compressed by stars in other regions

DH thinks arrows in wrong direction