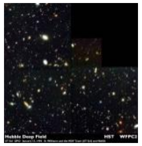
The Milky Way: Our Home Galaxy

- Since leaving the Solar System, we've concentrated on the nature of stars; i.e. how they generate their energy and evolve.
- Until about 1920, it was believed that the Universe was maybe uniformly filled with stars.
- **The truth is that stars group into larger entities, the galaxies, and our galaxy is called the Milky Way.**



The Appearance of the Milky Way (from the Earth)

- Have you ever seen the Milky Way? **(LC)**
- From the Earth, the Milky Way is a hazy band running generally north to south – looks similar to a cloud with the naked eye, but you need a dark sky.

- A small telescope, or even binoculars, reveals the cloud is actually composed of thousands or millions of stars (~100 billion, if you could see all of them).

- **Why does the Milky Way appear like this to us, i.e. a band of stars?**
  You always have to remember that we're on the inside looking out; no one one has ever seen the Milky Way from the outside. The fact that we see it as a band of stars, tells us that it is generally disk shaped.

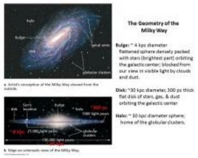
Characteristics of the Milky Way

How big is the Milky Way and what does it look like?

For measuring distances in the Milky Way, your author uses lightyears; **kiloparsecs** are also commonly used; a quick review of units:

- **1 lightyear (ly)** = distance that light travels in one year = $9 \text{ X } 10^{12}$ km
- **1 parsec (pc)** = distance that 1 AU subtends 1'' = 3.26 ly
- **1 kiloparsec (kpc)** = 1000 pc = 3260 ly; useful for inside the MW
- **1 megaparsec (Mpc)** = 10^6 pc = $3.26 \text{ X } 10^6$ ly; useful for extragalactic distances.

Based on observations and the appearance of other galaxies, the MW likely has this basic structure and size: bulge, disk, & halo.

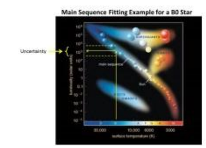


If we can only use stellar parallax to measure distances to stars out to about 1500 ly (~460 pc), how did we determine these distances?

Characteristics of the Milky Way

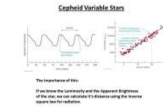
How did we determine these distances? Two Ways:

1. **Main Sequence Fitting** (also called Spectroscopic Parallax, *which is a lousy name*)
   - For Main Sequence stars (**roughly what fraction of stars are the MS (LC)**), we can always determine the Spectral Type and the Apparent Magnitude or Brightness



   - Then, the HR diagram gives the Absolute Magnitude or Luminosity.
   - If we know the Luminosity and Apparent Brightness, the inverse square law gives the distance.
   - Since the main sequence is a band, there is considerable uncertainty

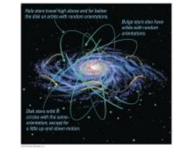
2. **Cepheid Variables**
   - In 1916, **Henrietta Leavitt** was studying stars call Cepheid Variables (**LC:** where did Leavitt work and what was her job?)
   - Cepheids are extremely luminous giant stars that pulsate



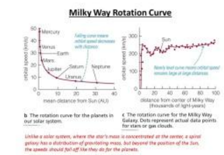
   - Leavitt discovered the **"Period – Luminosity" for Cepheids**
   - Using Cepheids, Harlow Shapley could measure the distance to globular clusters and determine the size of the MW.
   - Since Cepheids are so bright, they've been used to determine distances both inside and outside the MW *(more about this next class)*

The Motion of Stars in the Milky Way

Just like the planets in our solar system, the stars in the MW are in constant motion about the galactic center:



- Stars in the Bulge and the Halo follow randomly oriented orbits
- Stars and gas in the disk follow roughly circular orbits around the galactic center (***the Sun completes one orbit in about 220 million years***) with the following rotation curve:



What causes this flat rotation curve?

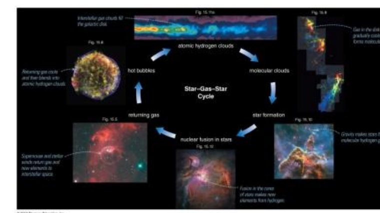
- As we'll see in Chapter 18, this is our first hint that there is perhaps more out there than we can see with any form of light: i.e. **Dark Matter**
- Dark Matter is thought to be nonluminous matter that is believed to exist in the halos of spiral galaxies
- The extra gravity from the dark matter produces the flat rotation curves
- **It is estimated that there must be about 10X as much Dark Matter in the Universe as normal luminous matter!**
- *We'll come back to this very important topic the last week of class.*

Galactic Recycling

- Your author has a nice section on the recycling of material by stars that goes on in the disk of the galaxy.

- This is closely tied to stellar formation and death, which we covered in chapter 13, so I'm going to leave most of this for your reading.

- I do want to call you attention to Fig 15.3 which is an excellent summary.



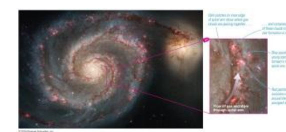
- This cycle constantly enriches the interstellar medium with heavy elements (*astronomers refer to these as metals, which for them, is anything heavier than Helium*) that are produced in stars and supernova explosions.

The Spiral Arms

Like most spiral galaxies, the stars in the disk of the MW likely form the characteristic spiral structure as in this image of the galaxy M51.

What are spiral arms?

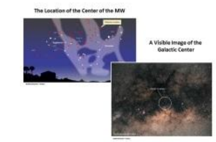
- At first, one might think the spiral arms is where the stars are, but then after a few orbits, the spiral arm would wrap around and disappear.
- For gas orbiting in a disk, spiral **density waves** are common
- When clouds of molecular gas and dust pass through the density wave, the clouds are compressed which triggers star formation.



- Bright O and B stars form which don't live long and die before the material gets very far from the density wave.
- **So, Spiral Arms = Density Waves + Formation of short-lived bright O & B stars. That's why we can see spiral arms.**
- Encounters with other galaxies can also form density waves.

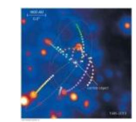
The Center of the Milky Way

The galactic bulge and the center of the galaxy are in the direction of Sagittarius, but both are hidden from our view in visible light by clouds of gas and dust.



For the last couple of decades, infrared and radio telescopes have been tracking what goes on near the center of the Milky Way. Why infrared and radio? **(LC)**
IR & radio can pass through the clouds of gas and dust that block our view of the galactic center.

All of these stars are orbiting something very massive called **Sgr A*** which is believed to be a supermassive blackhole with a mass ~ 4 million M_{sun}.



As we'll see in the next chapter, all galaxies, for which we can probe into the center, have a central black hole. *Why? Where do they come from? Do they have anything to do with how the galaxies formed?*
Nobody really knows yet. Some of these central black holes are accreting material and spewing out an incredible amount of radiation – the MW blackhole is quite quiet.

- **A wonderful summary by Dennis Overbye of the New York Times in 2018.**
- **Andrea Ghez, shared Nobel Prize with Reinhard Genzel** (saw him in BH video).
- **What has the Event Horizon Telescope seen?**