Astronomy 122

This Class (Lecture 22):

The Milky Way

HW9 due on Friday.

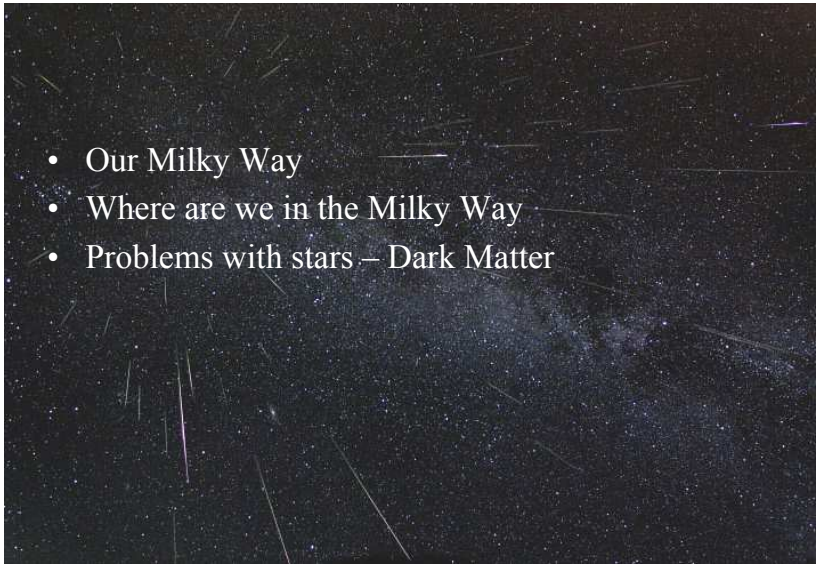
Nightlab report &/or makeup due in discussion class on Wednesday.

Next Class:

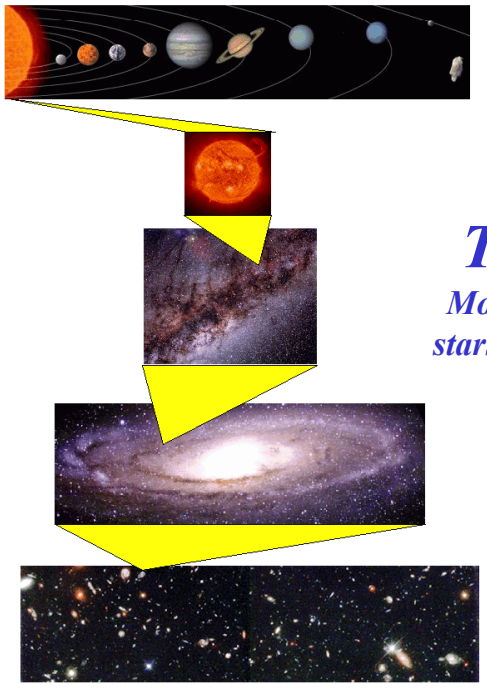
Galaxies

Music: *Under the Milky Way* – The Church

Outline



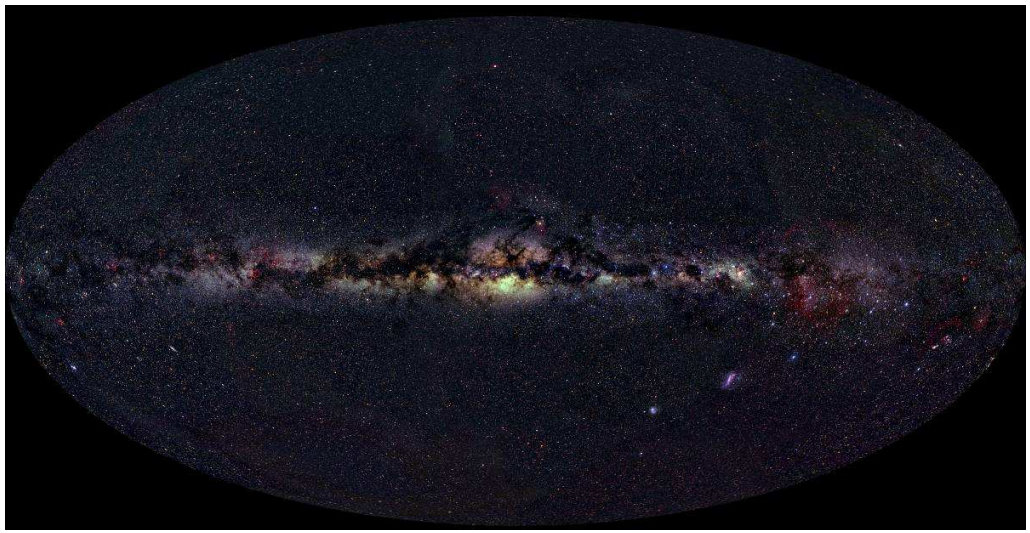
- Our Milky Way
- Where are we in the Milky Way
- Problems with stars – Dark Matter



Astronomy: The Big Picture

Moving from the birth/death of stars to a better understanding of the Galaxy!

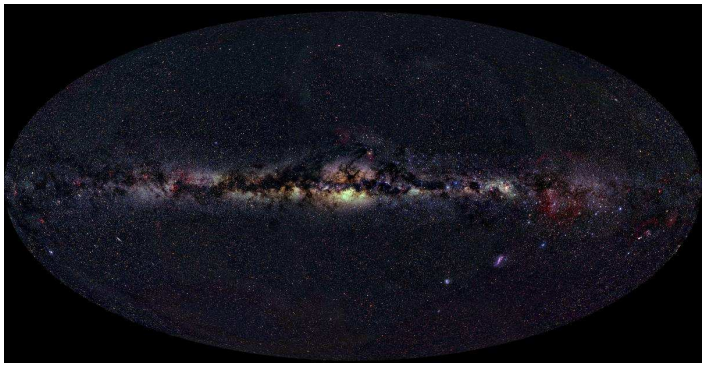
The Milky Way



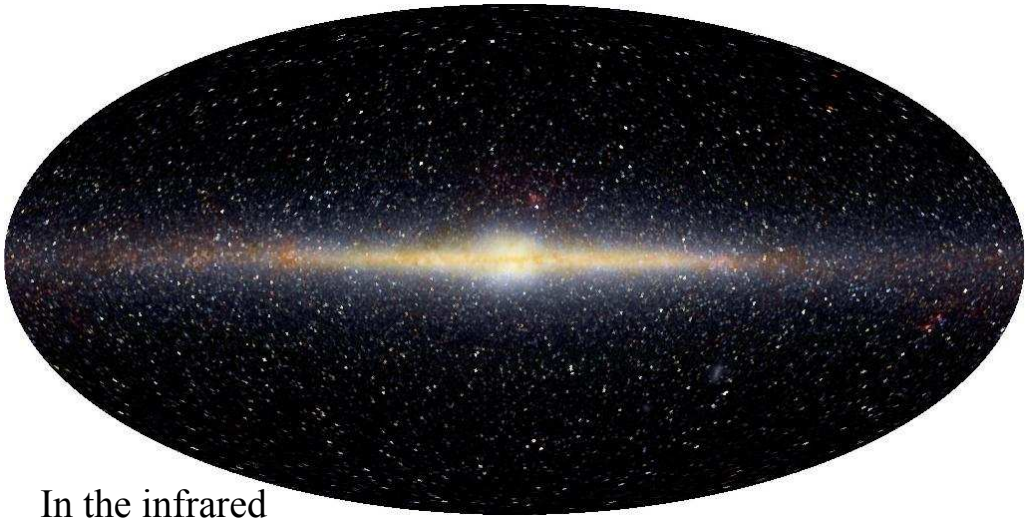
http://home.arcor-online.de/axel.mellinger/mwpan_aitoff.html

The Milky Way

- Our galaxy is a collection of stars, nebulae, molecular clouds, and stellar remnants
  - All bound together by gravity
  - Connected by the stellar evolution cycle



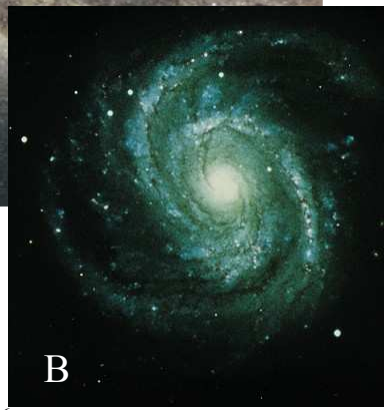
What is it?



In the infrared

http://antwrp.gsfc.nasa.gov/apod/image/0001/milkyway_cobe_big.jpg

Which is a picture of the Milky Way?



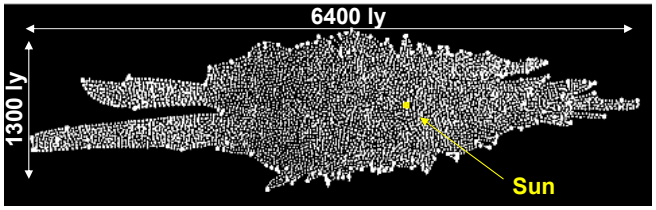
A is what we see from Earth inside the Milky Way. *B* is what the Milky Way "might" look like if we were far away looking back at our own galaxy from some other galaxy

The Milky Way is made of all the stars in our galaxy– about 100 billion. All the stars you can see in the sky are in our Galaxy.

Enormous clouds of dust obscure our view of most of the stars in our Galaxy

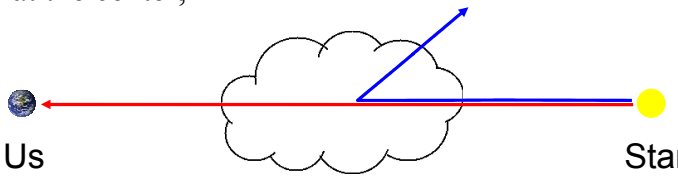
We Are in a Disk of Stars!

- The number of stars were counted in all directions from the Sun by Herschel (the guy who discovered Uranus) and his sister Caroline
- They assumed that all stars have the same brightness and that space is completely transparent **– Bad assumption!**
- They concluded that the Sun is at the center of the Universe **– Nope!**



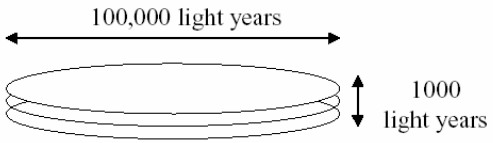
The Importance of Being Earnestly Dust

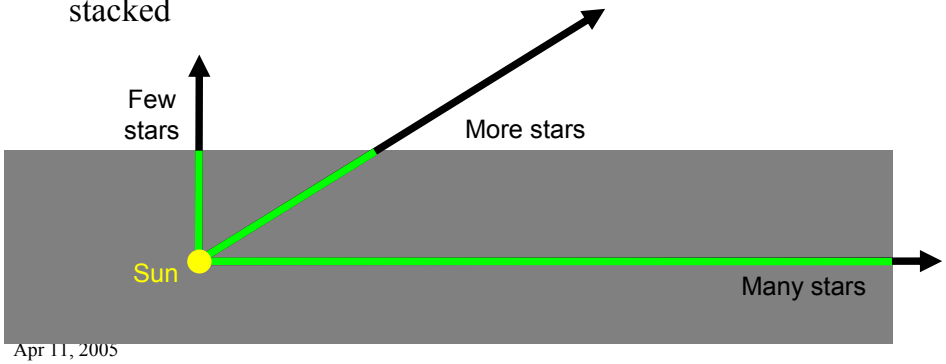
- There is clearly dust in the Milky Way disk. How does dust effect the measurement?
  - Makes stars dimmer and redder
- There is more dust toward Galaxy center.
- Consequence: Under-estimation in the number of stars in one direction
- We appear to be at the center, but we're not!



But, We Are in a Disk of Stars!

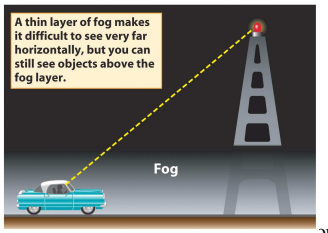
- But they were correct in determining that the distribution of stars in the Milky Way is in a thin disk
- The Milky Way is very thin in comparison to its diameter – imagine 3 CDs stacked





How Do We Find the Center?

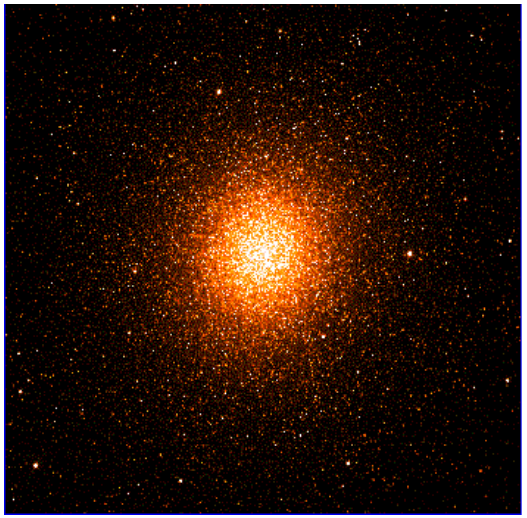
- If dust blocks our view, how do we find the center?
- We need to look outside of the disk!
  - Get around the dust
- A collection of relatively bright objects, outside the disk.



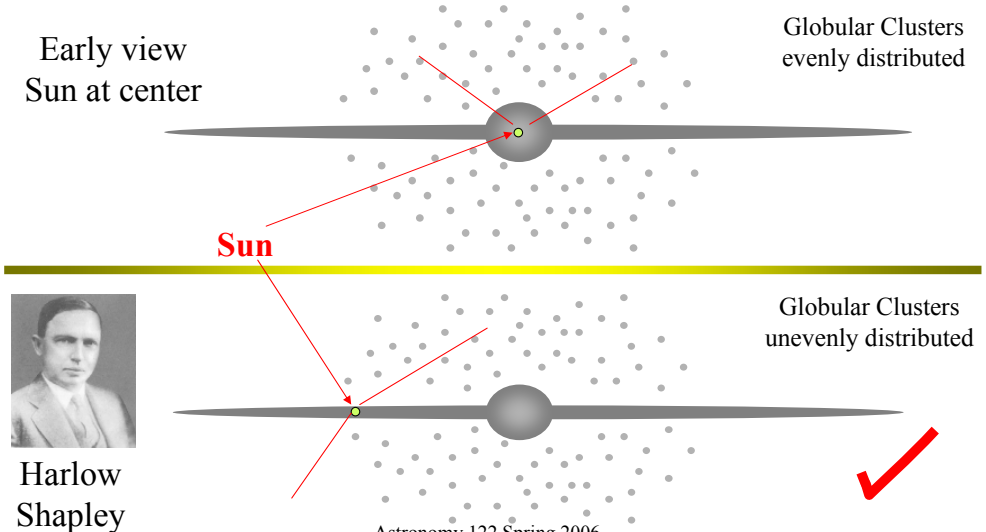
Determining your position in the fog

Globular Clusters

- Extremely regular, gravitationally bound groups of stars– very dense
- About 10^5 – 10^6 stars each
- HR diagram of these groups of stars show that they are very old– 10 billion years!
- Generally outside disk of the Galaxy
- About 150 known orbiting our Galaxy



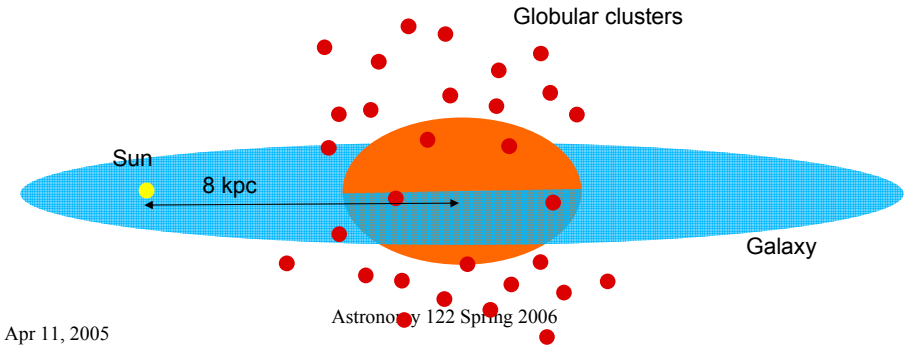
Finding Our Place



Harlow Shapley

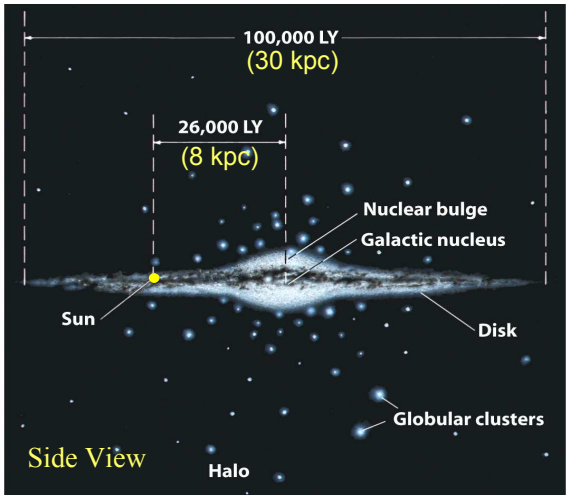
Our Place

- Shapley showed that we are not the center of the Galaxy in the 1920s.
  - **2nd Copernican revolution!**
- All of the globular clusters are orbiting around a point in Sagittarius– 25000 lyrs or 8000 parsecs away.
- That must be the center of our Galaxy.



The Structure of Our Galaxy

- Disk
  - All kinds of stars, many younger
  - Open clusters
  - Gas and dust
- Halo
  - Old, red dwarfs and giants
  - Little gas and dust
  - Globular clusters
- Bulge
  - Mixture of halo and disk



The Disk

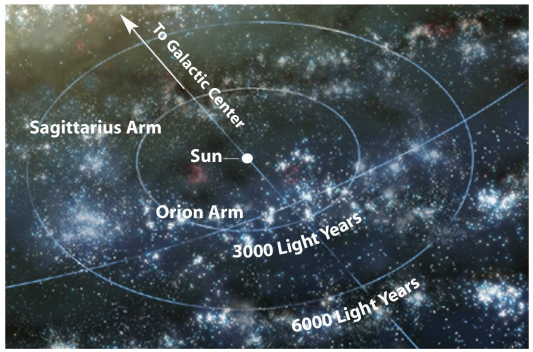
- The disk of our Galaxy contains most of its visible mass
  - 90% of the Galaxy's stars
- Its where "the action" occurs
  - Star formation, nebulae, etc..
- Relatively thin
  - 700 parsecs thick vs. 30,000 parsecs across

Spiral Arms?

- Other disk galaxies show spiral arms
  - Made of O- & B-type stars, diffuse nebulae, and giant molecular clouds
- How do we know our Galaxy has them?
- It's the problem of not seeing the forest for the trees

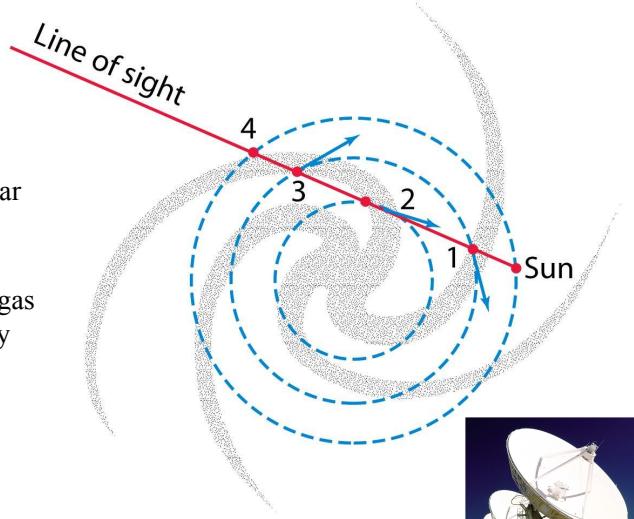
Hints of Spiral Arms

- We plot the locations of nearby O- and B-type stars in our Galaxy
- Find the stars are arranged in arms
- Our Sun is in-between spiral arms
- But we can't see beyond a few thousand light years
- What about the rest of the Galaxy?

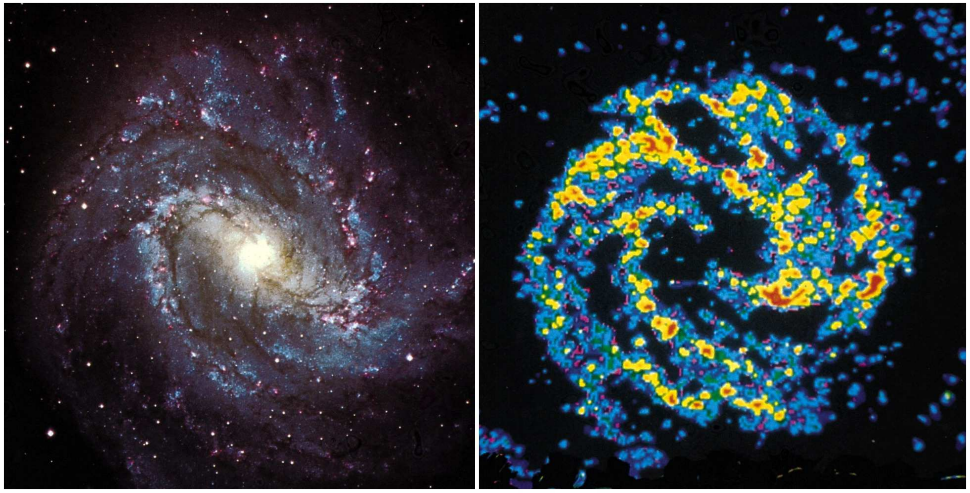


Seeing the Galaxy in Hydrogen Emission

- Look for 21-cm wavelength photons
  - Emitted by interstellar hydrogen – most abundant stuff!
  - Easily pass through gas & dust along the way
  - Map the Galaxy!



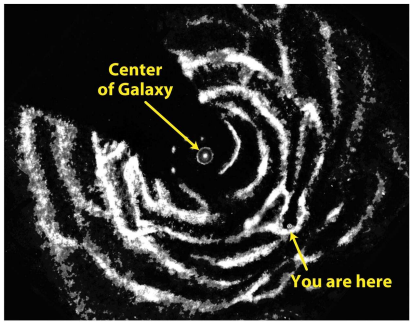
Visible and Radio

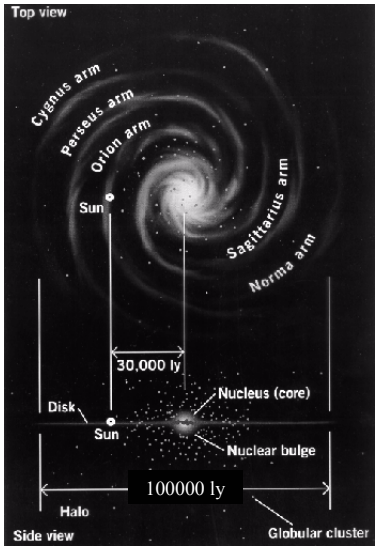


M83

The Galaxy's Spiral Arms

- The 21-cm radio emission shows the spiral arms (below)
- We find five main arms in the Galaxy (right)





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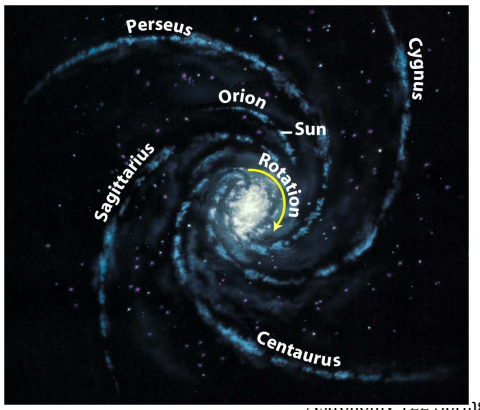
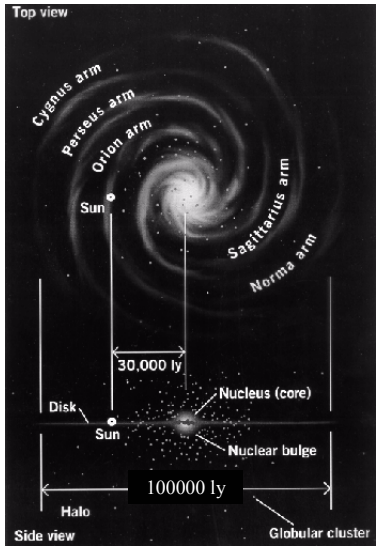


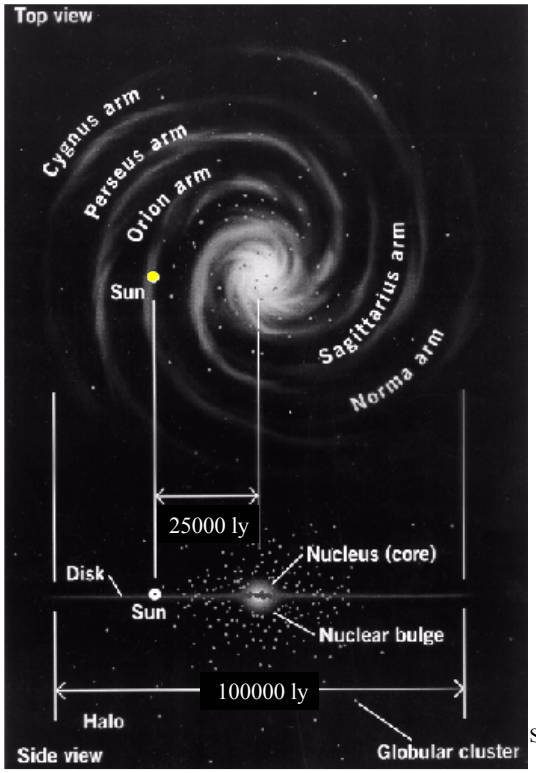


The Galactic Halo

- Our Galaxy's disk is surrounded by a spherical halo of stars & globular clusters
  - Red dwarfs and red giants – old stars
  - Only about 2% the number of stars in the disk
- There is some structure to the halo
  - Denser towards the center
  - Two sets of globular clusters
    - Outer clusters – older, spherical distribution
    - Inner clusters – slightly younger (but still old), flattened spherical distribution

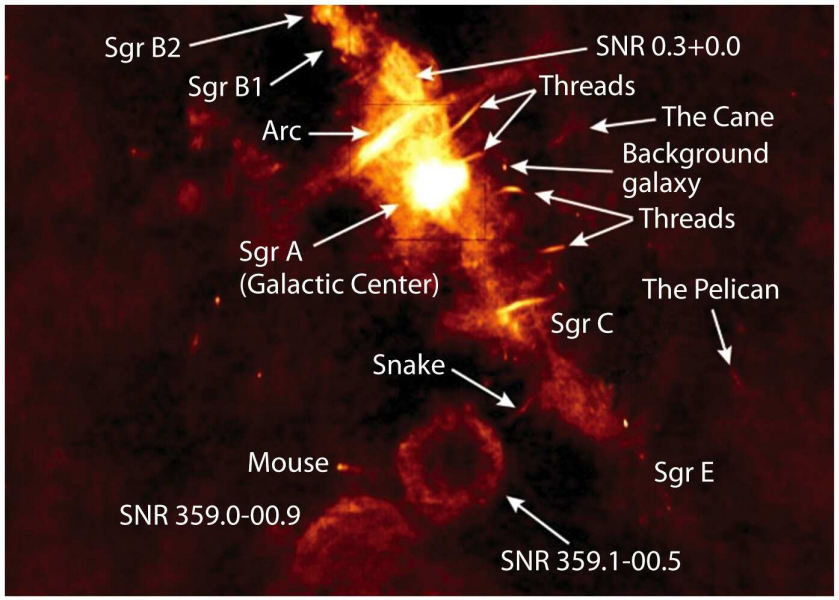
The Bulge

- The region where the disk and the halo merge
  - About 2,000 pc across
  - Contains about 10% of the Galaxy's stars
- Mix of primarily old stars, but also contains some young stars and gas & dust
- Like an extension of both the disk and halo



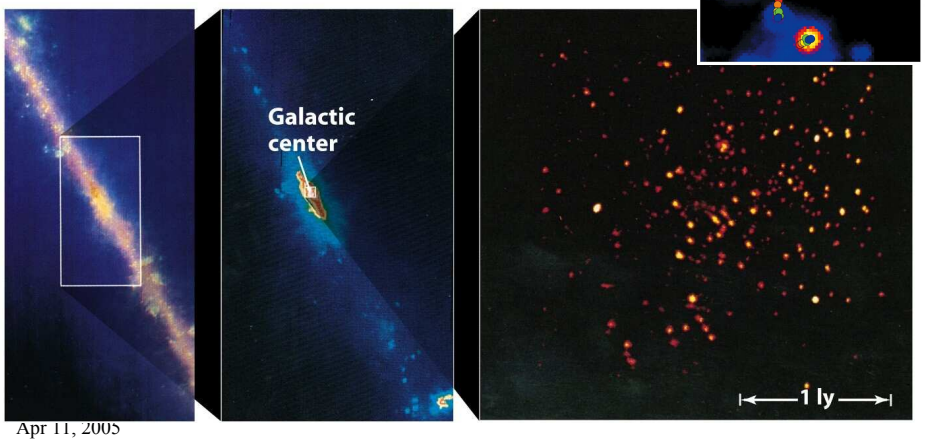
Our Galaxy

The Center of Our Galaxy



The Galactic Nucleus

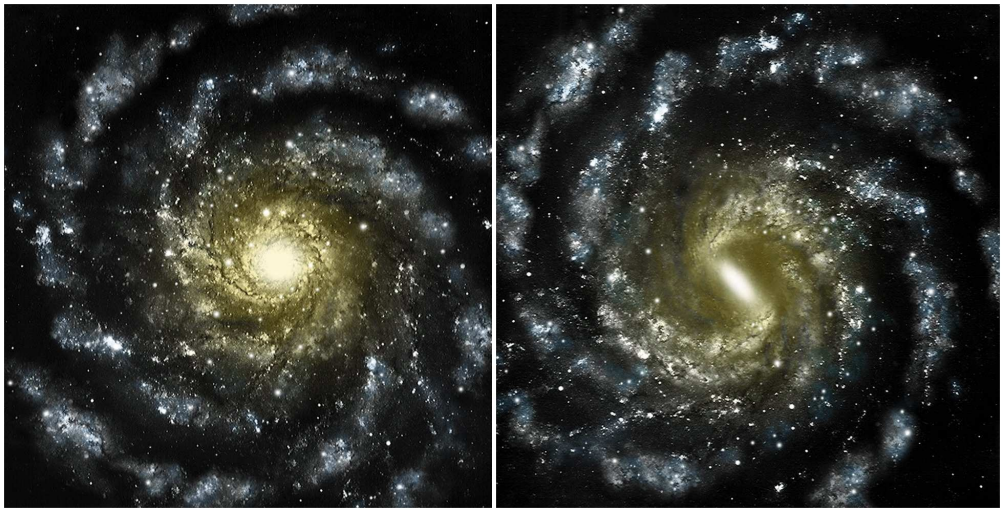
- Buried in the center of the bulge
- 8,000 pc away
- Incredibly dense region of stars and gas



Thought Question

Massive O-type stars are not found in the Galactic halo. What can we conclude from this?

Do Galaxies Spin?



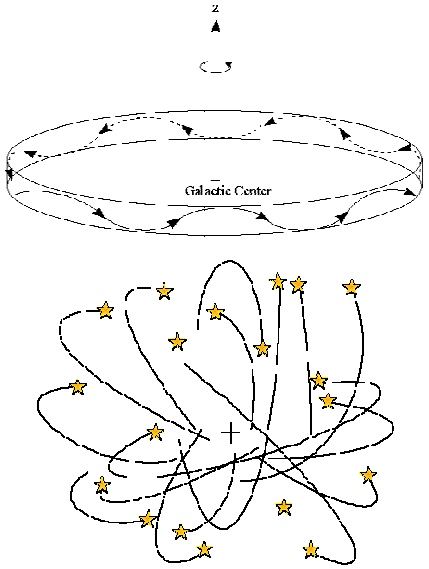
Spiral galaxies really suggest it. BTW, our Galaxy probably looks more like the right galaxy.

Rotation of the Galaxy

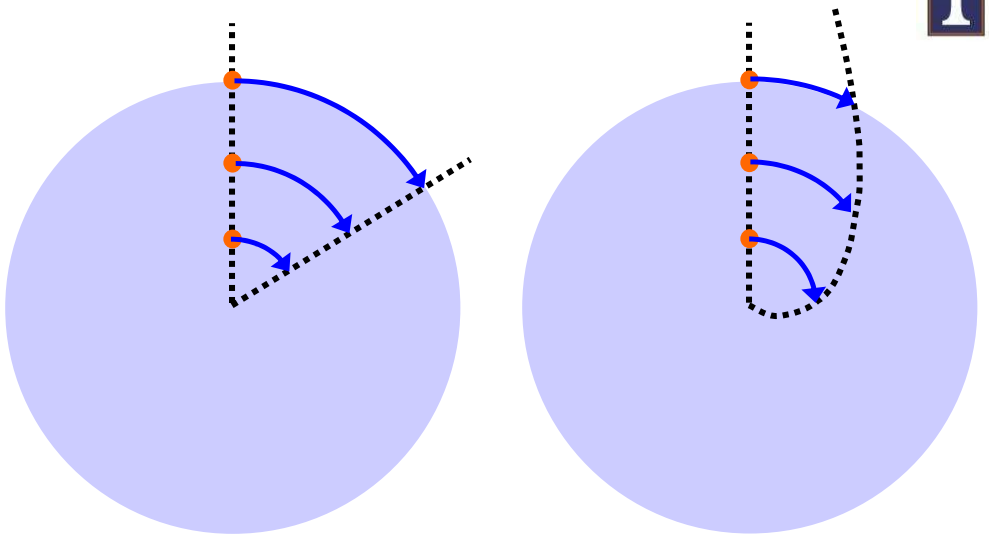
- Similar to the planets orbiting the Sun, the stars and gas of the Galaxy orbit the nucleus
- How does the Galaxy rotate?
- Like a CD? DVD?
- How about disk vs. halo?
- Measure Doppler shifts to find out.

Rotation of the Galaxy

- Stars in the disk all orbit the Galaxy in the same direction
  - Stay in the disk (they may drift up and down)
  - Orbits roughly circular
- Stars in the halo and bulge orbit the Galactic nucleus randomly
  - No organization to the orbits
  - Many very elliptical orbits



Solid vs. Differential Rotation

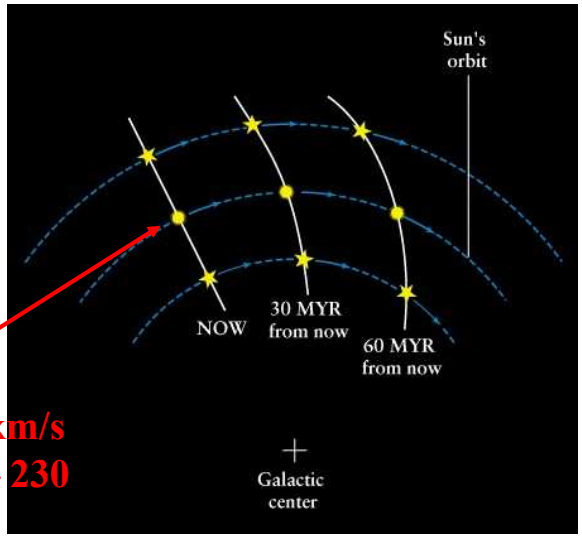


Same angular speed
(degrees per year)

Same linear speed
(parsecs per year)

Is the Solar System Moving Too?

Yes… the whole Galaxy has differential rotation– us included

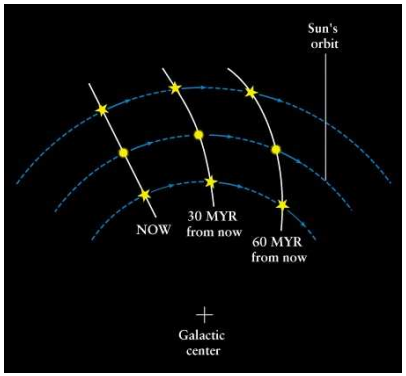


The Sun orbits at 220 km/s or about 500,000 mph– 230 million years per orbit!

Wow! That's fast!

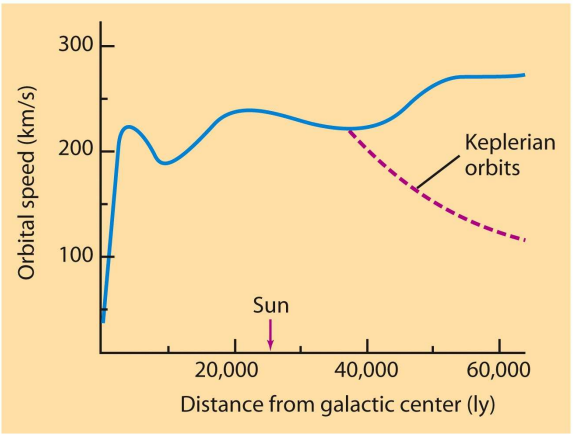
Stop and think about it.

- **That's traveling to Chicago in 1 second!**
- But Milky Way is big!
- Only orbited 50 times!
- Last time the Sun was here, the dinosaurs were just starting out.
- ¼ way around, they were extinct!



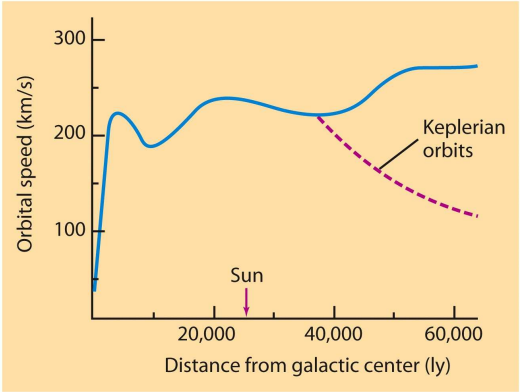
The Rotation of the Galaxy

- Effectively use Kepler's 3rd law to find mass.
- There is 10^{11} solar masses inside of our orbit.
- Since we know our speed, we can measure the orbital speed of the other stars.
- V is constant from 2kpc out.



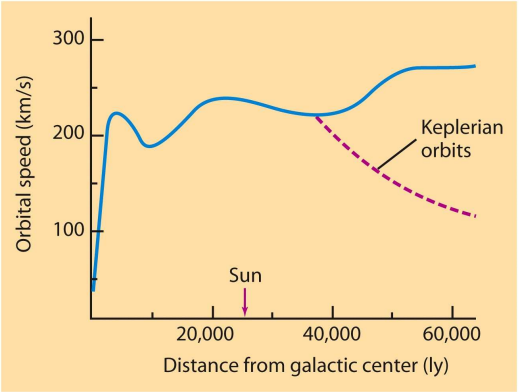
Whaa?

- Velocity does not drop off with stars, gas, or dust
- It is still constant, or even increasing
- There must be a lot of mass at farther radii that is not glowing at any wavelength.
- Dark Matter!



Rotation Curve Shows Hidden Mass

- The farther a star is from the center, the slower it should orbit
- Observations show that speed actually increases or is constant with distance from the center
- There must be **a lot** of mass in the outer parts of the Galaxy
- But only 20% of the Galaxy's light is outside the orbit of the Sun
- The mass in the outer part of the Galaxy is **dark**



Dark Matter

- What is this dark matter?
- Must have mass and must not glow. To be precise, must be very dim.
- Dark matter is of unknown origins, although several hypotheses exist:
  - Low-mass stars (old) WD
  - Brown dwarfs
  - Black Holes
  - Neutrinos
  - Massive interstellar dust grains
  - Planets
  - Exotic subatomic particles
  - Old socks
  - Lint… etc..

Dark Matter

- The dark matter in the Galaxy is in greatly extended halo
  - Up to 90% of the Galaxy's mass is dark matter!
  - Galaxy may have over a trillion solar masses total!