

Astronomy 150: Killer Skies



This Class (Lecture 29):
Our Galaxy

Next Class:
Nearby Galaxies

**HW 10 & Computer Lab
due Monday**

Music: Galaxies – Laura Viers

Outline

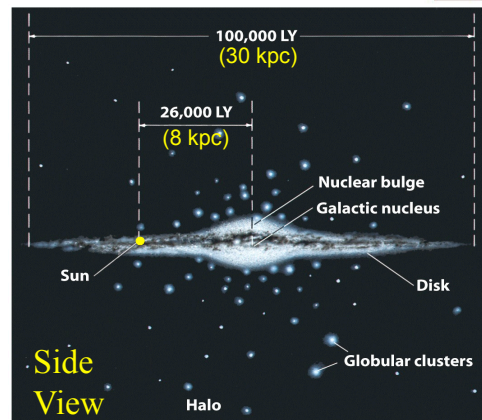


- The structure of the Milky Way (a collection of stars, nebulae, dust, stellar corpses, planets..)
 - The disk
 - The halo
 - The bulge
 - The spiral arms
- How do we orbit the Galactic center?

Our Galaxy



- Globular clusters– oldest stars
- Galactic nucleus– dense collection of stars (center of Galaxy)
- Nuclear bulge– mostly old stars, but very densely packed
- Spiral arms and the disk– mostly young stars and lots of dust
- Note position of the Sun, just over half way out.



The Disk



- The disk of our Galaxy contains most of its visible mass
 - 90% of the Galaxy's stars
- It's where “the action” occurs
 - Star formation, nebulae, etc..
- Relatively thin
 - 1,000 lyrs thick vs. 100,000 lyrs across



Spiral Arms?



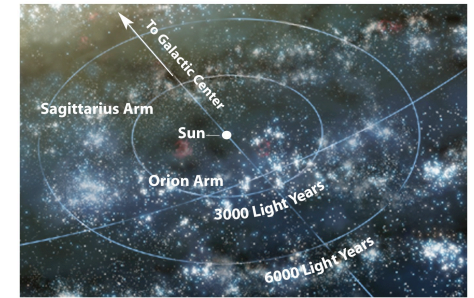
- Other disk galaxies show spiral arms
 - Made of O- & B-type stars, diffuse nebulae, and most of the giant molecular clouds
- How do we know our Galaxy has them?
- It's the problem of not seeing the forest for the trees



Hints of Spiral Arms



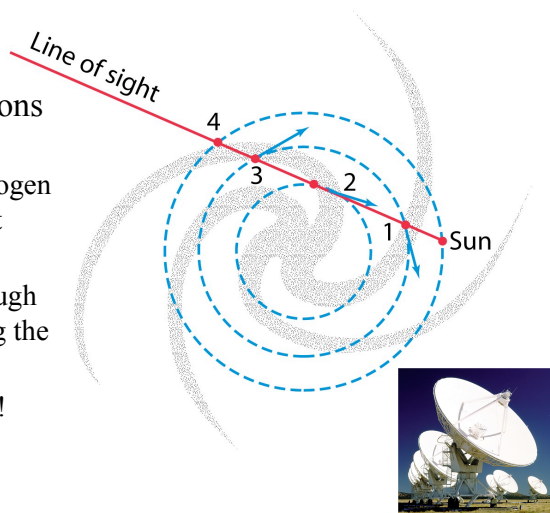
- We plot the locations of nearby O- and B-type stars in our Galaxy
- Find the stars are arranged in arms
- Our Sun is in-between spiral arms
- What about the rest of the Galaxy?



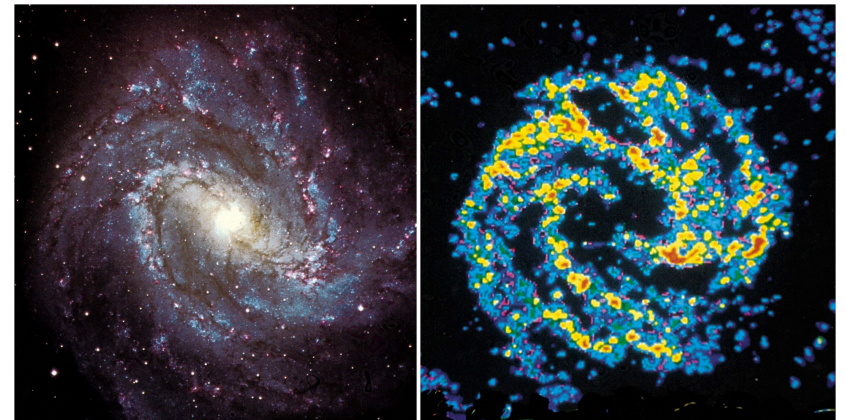
Seeing the Galaxy in Hydrogen Emission



- 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

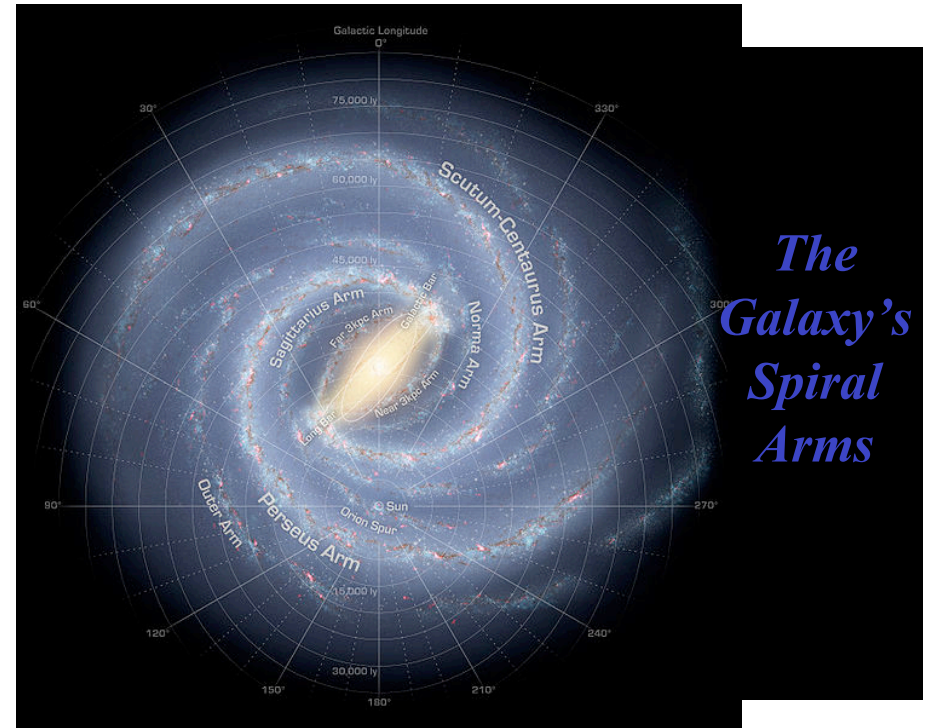
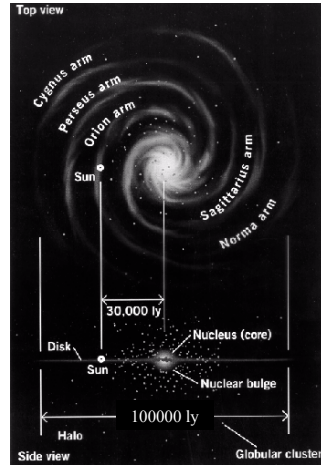
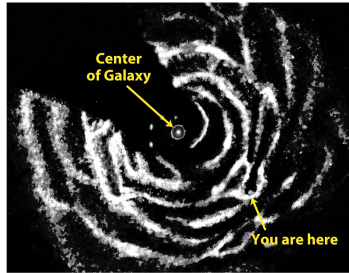


M83

The Galaxy's Spiral Arms

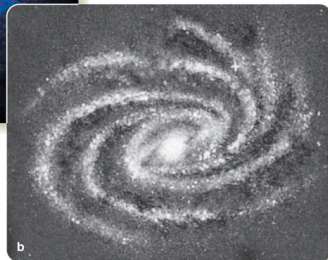
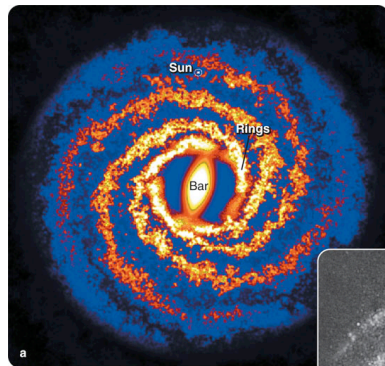


- The 21-cm radio emission shows the spiral arms (below)
- We find five main arms in the Galaxy (right)



The Galaxy's Spiral Arms

The Galaxy's Spiral Arms



The Galactic Halo



- Our Galaxy's disk is surrounded by a spherical halo of old stars & globular clusters
 - Red dwarfs and red giants – old stars
 - Only about 2% the number of stars in the disk



The disk in infrared light

The Bulge



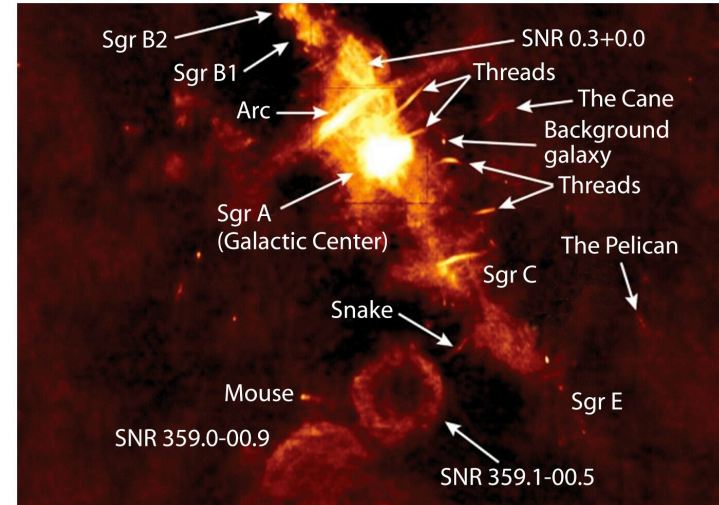
- The region where the disk and the halo merge

- 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

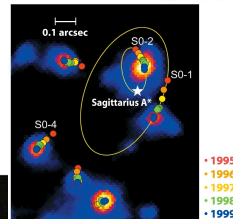
The Center of Our Galaxy



The Galactic Nucleus



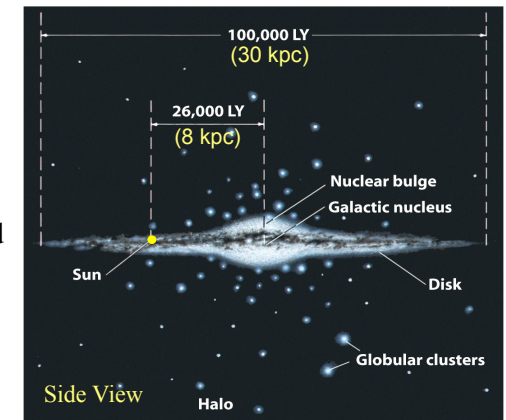
- Buried in the center of the bulge
- 21,000 lys away
- Incredibly dense region of stars and gas



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



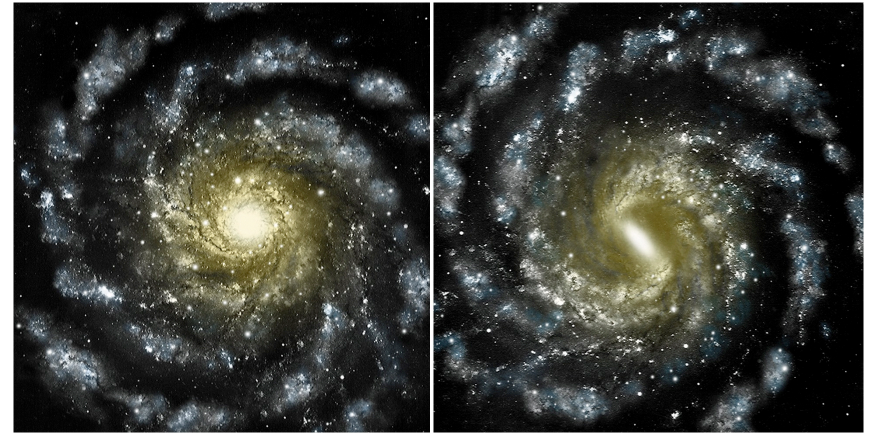
Question



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

- a) Massive stars never formed in the halo.
- b) The halo consists of only old stars.
- c) Massive stars can only be formed now.
- d) The halo was accreted from another galaxy.

Do Galaxies Spin?



Spiral galaxies really suggest it. Our Galaxy probably looks more like the right galaxy.

Rotation of the Galaxy



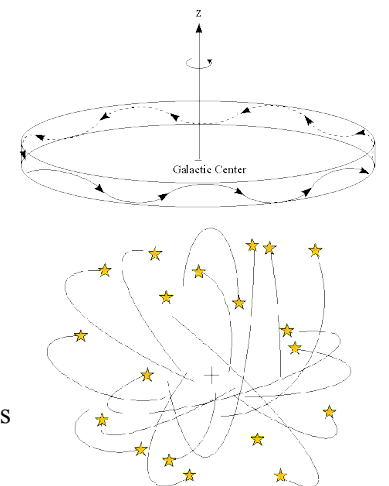
- Similar to the planets orbiting the Sun, the stars and gas of the Galaxy orbit the nucleus
- How does the Galaxy rotate?
- Like a DVD?



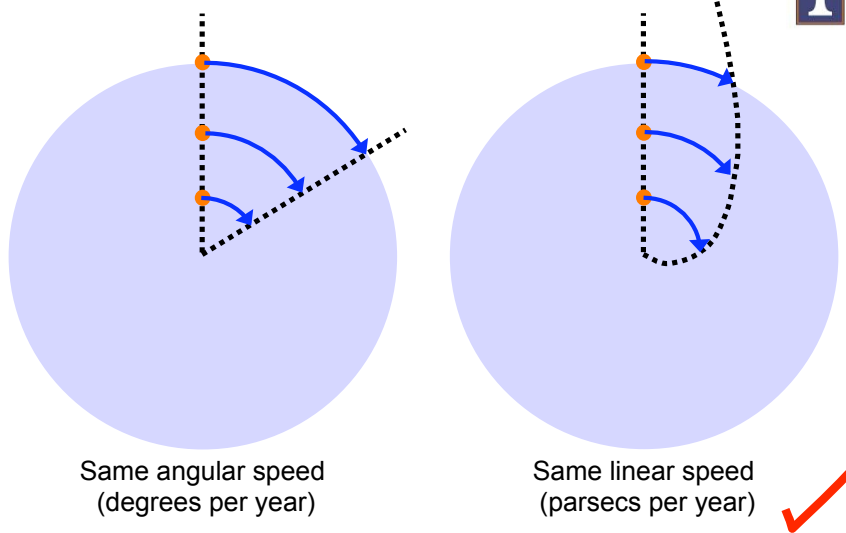
Rotation of the Galaxy



- 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

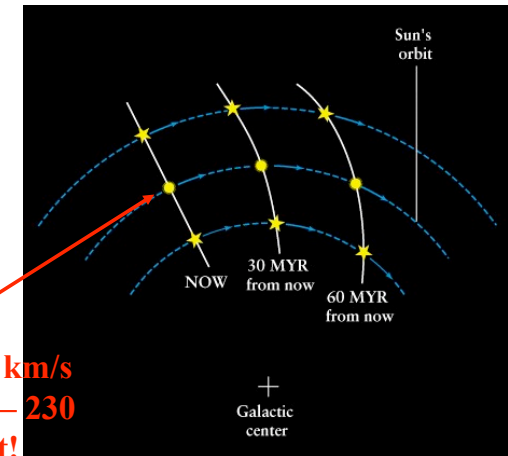


Is the Solar System Moving Too?



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!

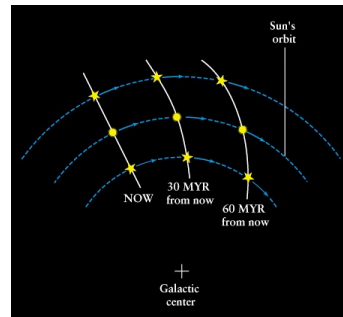


Wow! That's fast!



Stop and think about it.

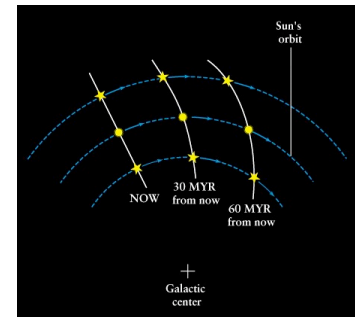
- **That's traveling to Chicago in 1 second!**
- But Milky Way is big!
- Earth has only orbited 50 times!
- Last time the Sun was here, the dinosaurs were just starting out.
- $\frac{1}{4}$ way around, they were extinct!



Wow! That's fast!



What if we run into a molecular cloud?
Molecular clouds are in spiral arms.. More likely.

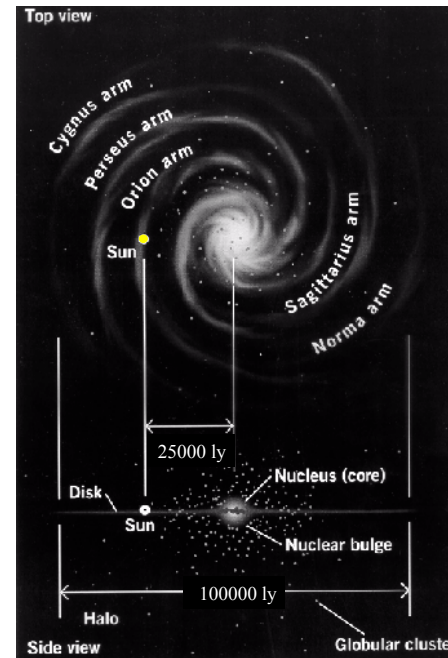


Question



The Galaxy can be thought of as

- a) A static thing
- b) A DVD
- c) A stack of three DVDs, but with differential rotation
- d) As a closed system with a hydrostatic solution
- e) A stack of three DVDs, but with solid body rotation



Our Galaxy

Galaxy Song



Monty Python's The Meaning of Life (1983)

Question



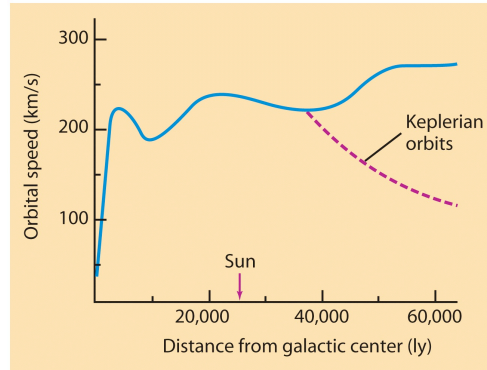
In the Milky Way, the Sun is located

- a) in the halo.
- b) in the disk.
- c) in the center.
- d) in a globular cluster.
- e) in the bulge.

The Rotation of the Galaxy



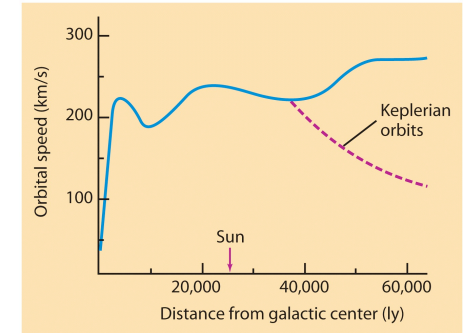
- Since we know our speed, we can estimate how much mass inside our orbit.
 - Kepler's Laws for those who know,
- 10^{11} solar masses.
- Since we know our speed, we can measure the orbital speed of the other stars.
- V is constant from 5000 lyrs out.



Whaa?



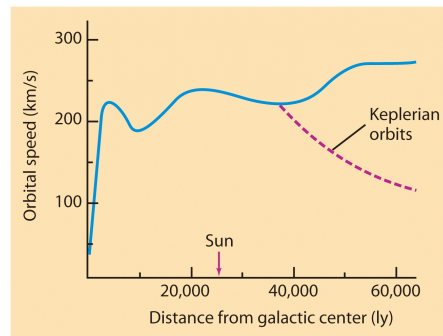
- Something weird.
- Velocity does not drop off with stars, gas, or dust
- It is still constant, or even increasing



Rotation Curve Shows Hidden Mass



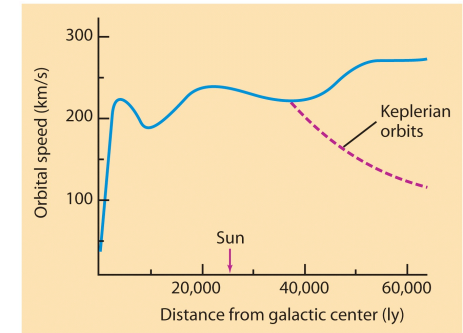
- Just as in the Solar System, the farther away from the mass, the slower something orbits.
 - Compare Pluto and Mercury's orbital speed.
- But, observations of stars in the outer Galaxy show that their speed actually increases or is constant with distance from the center!



Rotation Curve Shows Hidden Mass



- 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 must be something **dark**.



Dark Matter

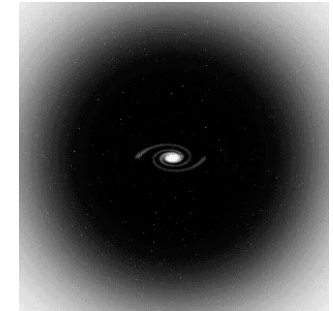


- What is this dark matter?
- Must have mass and must not glow. To be precise, must be very dim.
- Dark matter is of unknown origins, although several hypotheses exist:
 - Low-mass stars (old) WD
 - Brown dwarfs
 - Black Holes
 - Neutrinos
 - Massive interstellar dust grains
 - Planets
 - Exotic subatomic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

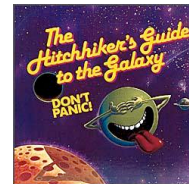


Question



In the Milky Way, most of the mass is

- a) stars.
- b) stellar corpses.
- c) dark Energy.
- d) dark matter.
- e) neutrinos.



Space is Big!



“Space is big. Really big. You just won't believe how vastly hugely mind-bogglingly big it is. I mean, you may think it's a long way down the road to the chemist, but that's just peanuts to space...”

To be fair though, when confronted by the sheer enormity of the distances between the stars, better minds than [ours] have faltered.

The simple truth is that interstellar distances will not fit into the human imagination.”

--Douglas Adams

The Hitchhiker's Guide to the Galaxy