Astronomy 150:

Killer Skies

This Class (Lecture 28):
More Milky Way

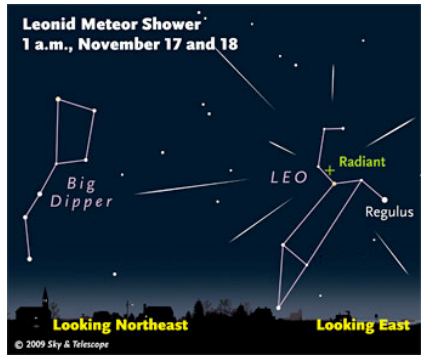
Next Class:
Nearby Galaxies

HW 10 due on 2nd Sunday

Music: Under the Milky Way – *The Church*

Leonid Meteor Shower

- Nov. 17, 2009
- The 2009 Leonids could produce more than 500 shooting stars/hour in Asia.
- US will not have the best view (~25/hour), but it should be the strongest shower in quite some time.
- Better estimate is 3am on Tuesday morning/tonight, then just as it gets dark on Tuesday night, but the latter is less likely to be impressive.

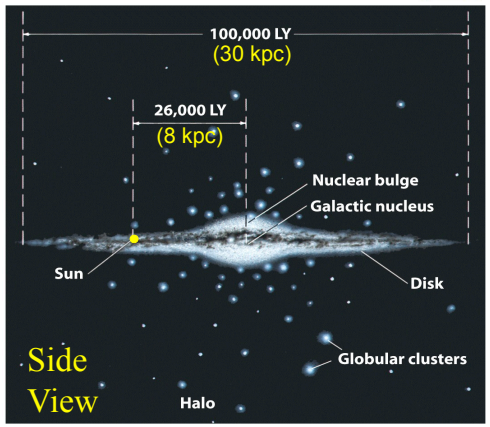


Outline

- 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 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

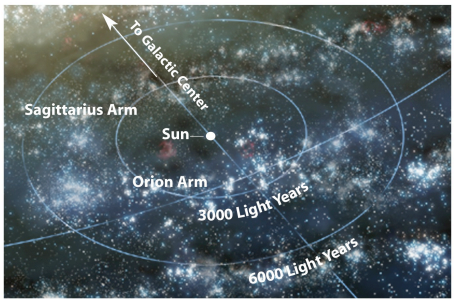
- It's where "the action" occurs
  - Star formation, nebulae, etc..
- Relatively thin
  - 1,000 lyrs thick vs. 100,000 lyrs across

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

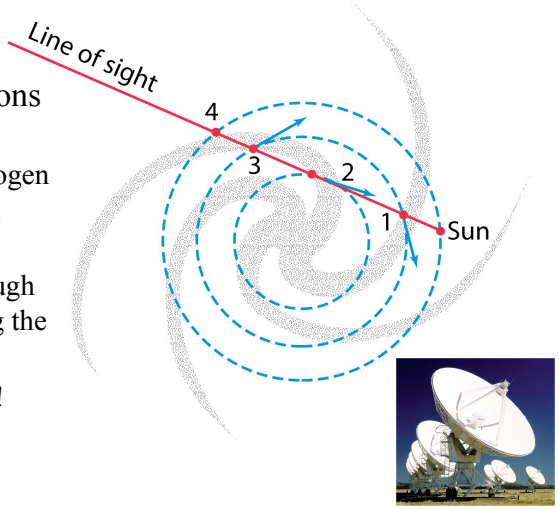
Hints of Spiral Arms

- 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?

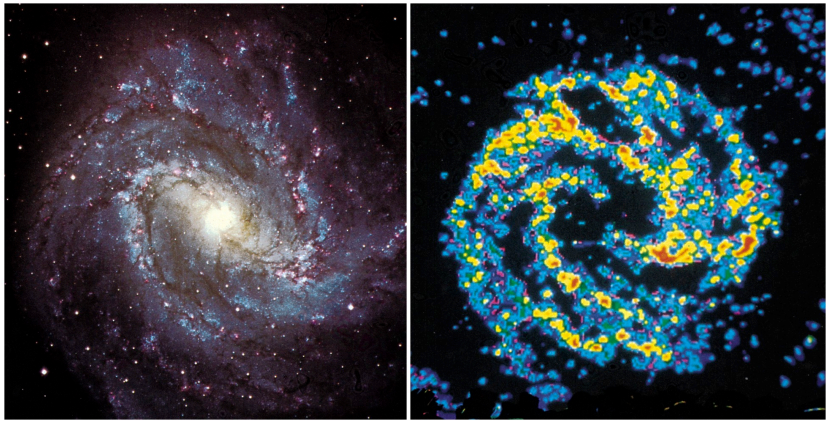


Seeing the Galaxy in Hydrogen Emission

- 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



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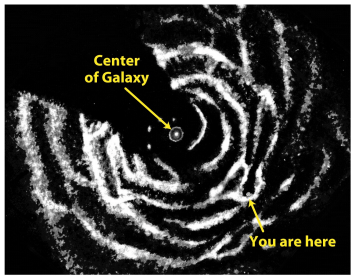
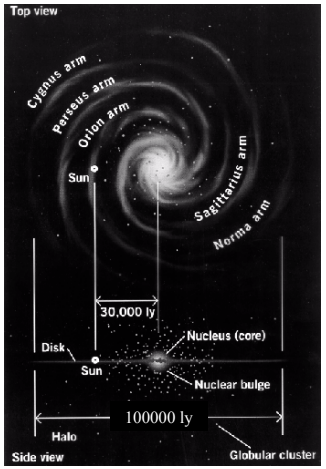
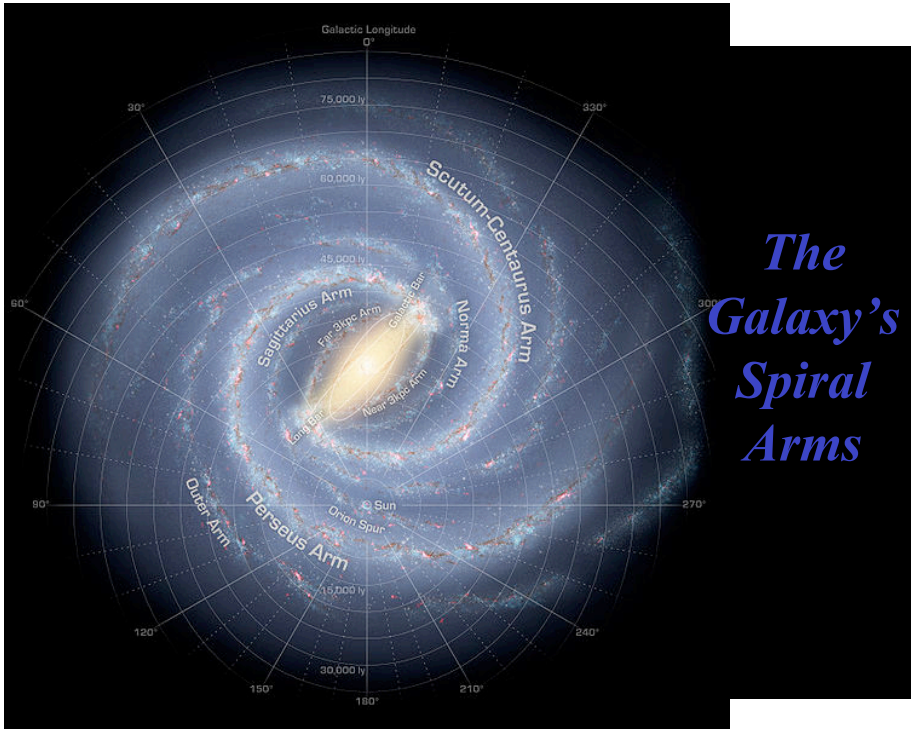
The Galaxy's Spiral Arms

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

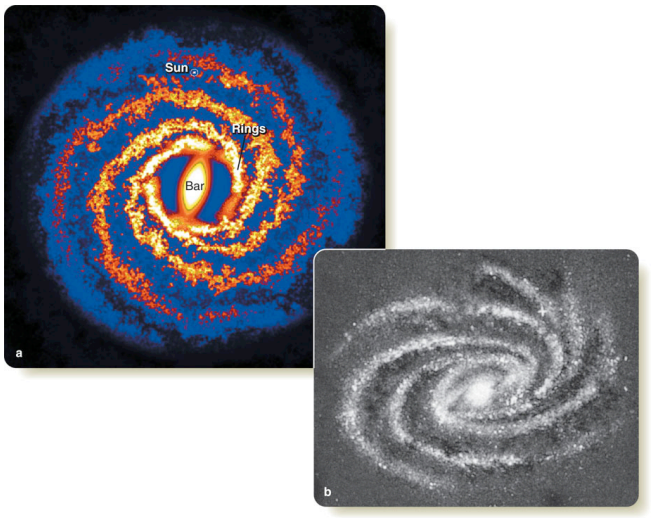






The Galaxy's Spiral Arms

The Galaxy's Spiral Arms



The Galactic Halo

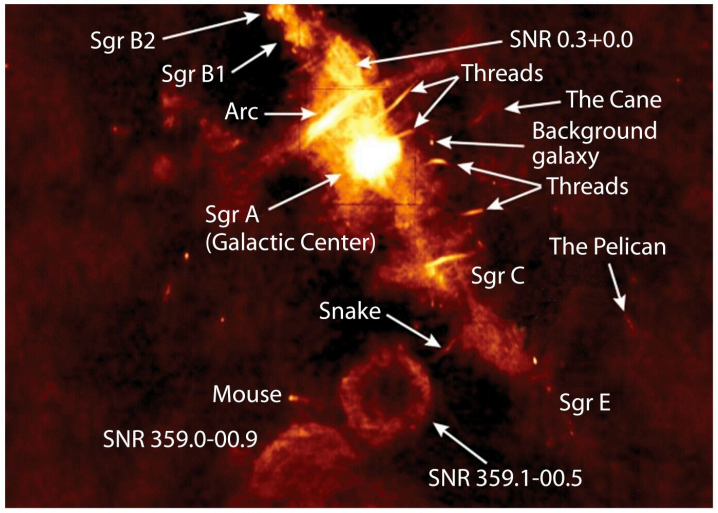
- Our Galaxy's disk is surrounded by a spherical halo of old stars & globular clusters
  - Red dwarfs and red giants – old stars
  - Only about 2% the number of stars in the disk

The 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

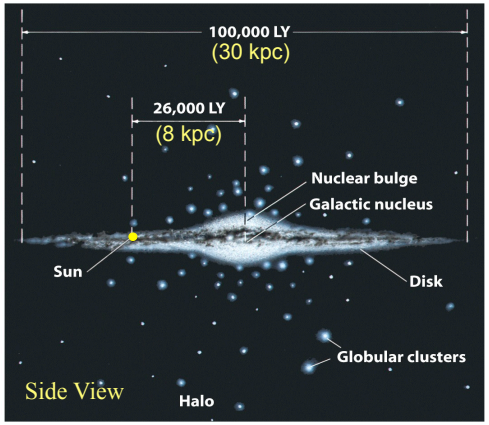


The Galactic Nucleus

- 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

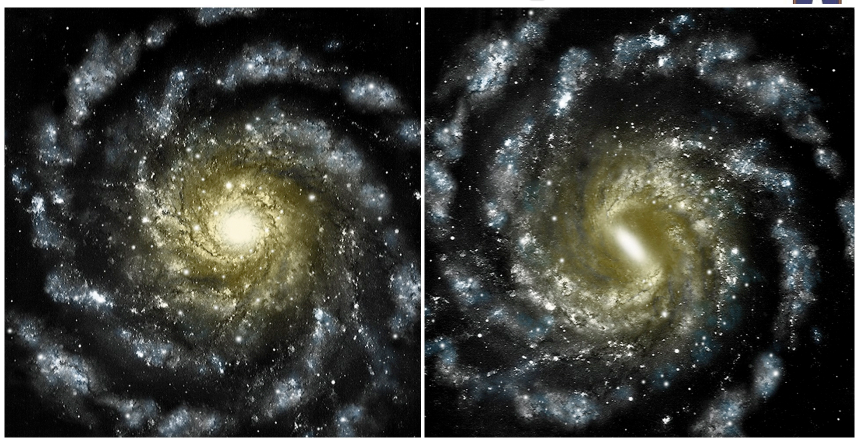


Question

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?



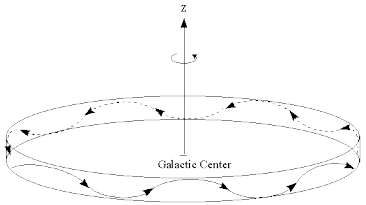
Spiral galaxies really suggest it. Our Galaxy probably looks more like the right galaxy.

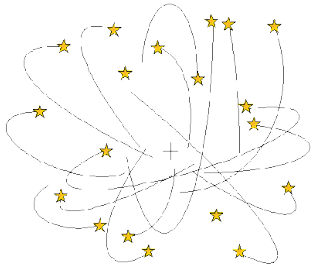
Rotation of the Galaxy

- 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?

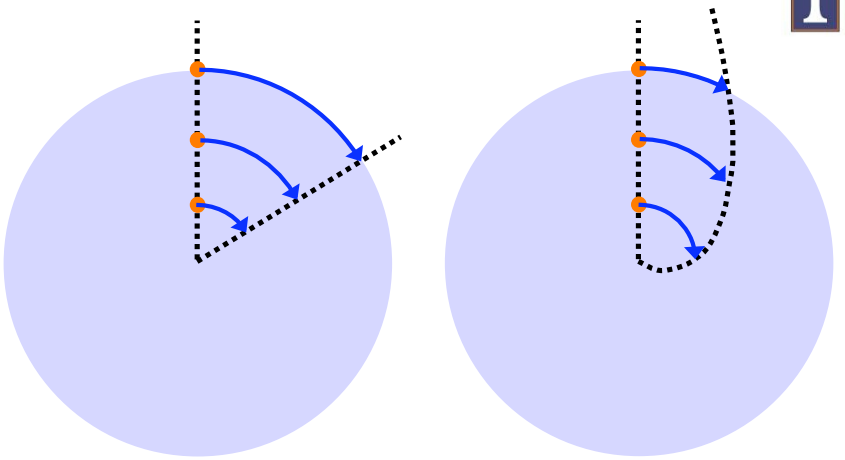
Rotation of the Galaxy

- 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

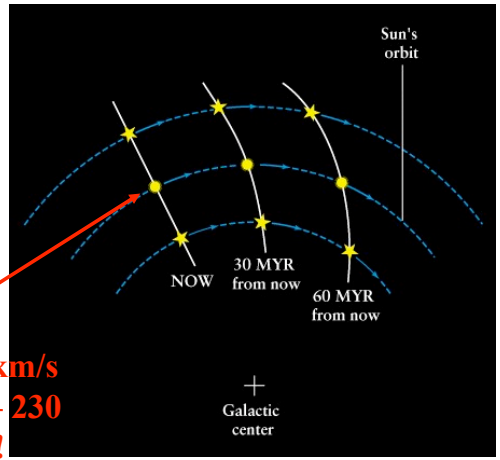


Same angular speed
(degrees per year)

Same linear speed
(parsecs per year)

Is the Solar System Moving Too?

Yes… the whole Galaxy has differential rotation– us included

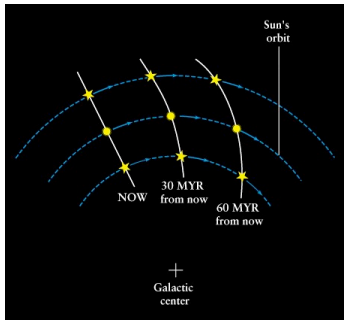


The Sun orbits at 220 km/s or about 500,000 mph– 230 million years per orbit!

Wow! That's fast!

Stop and think about it.

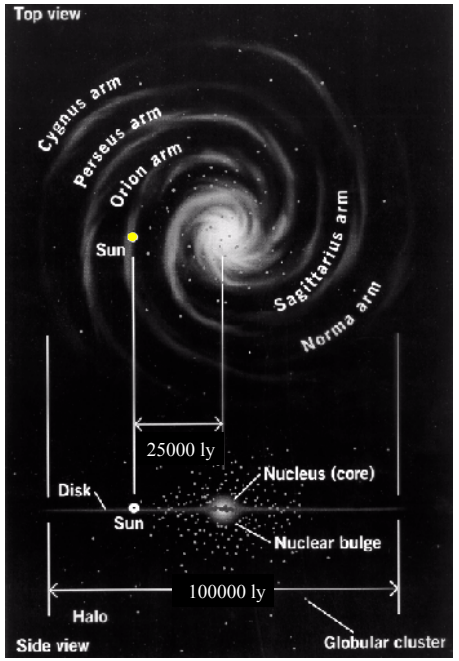
- **That's traveling to Chicago in 1 second!**
- But Milky Way is big!
- Earth has only orbited 50 times!
- Last time the Sun was here, the dinosaurs were just starting out.
- ¼ way around, they were extinct!



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)

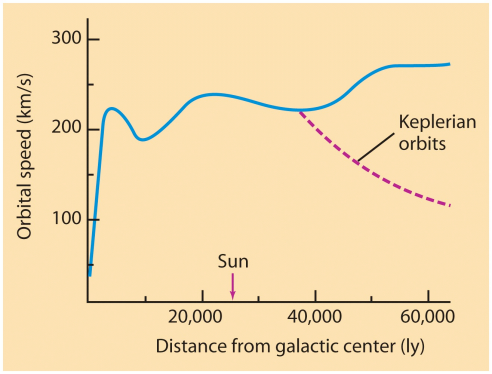
Question

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.

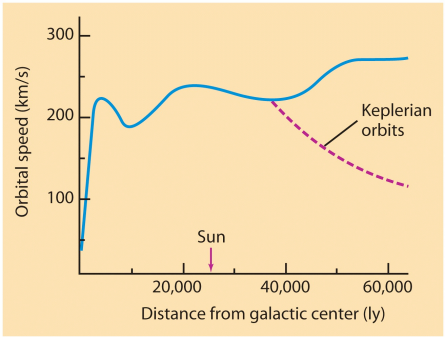
The Rotation of the Galaxy

- 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 2kpc out.



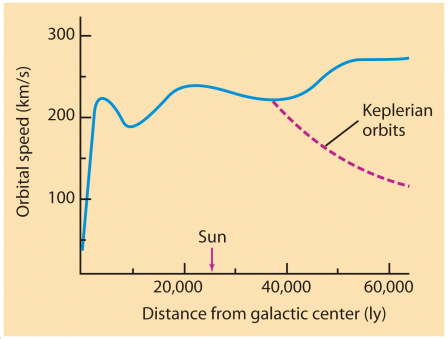
Whaa?

- Something weird.
- 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!



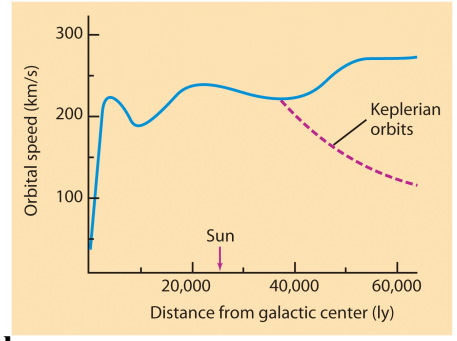
Rotation Curve Shows Hidden Mass

- 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.**

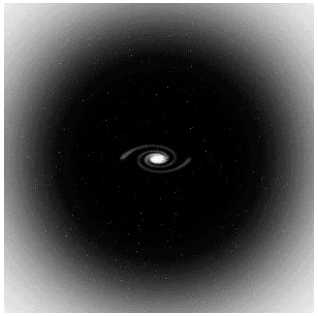


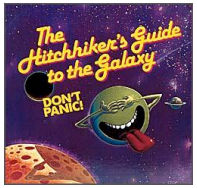
Dark Matter

- 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!





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

"Spiral Nebulae"

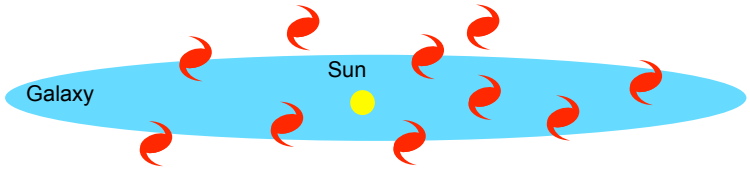
- Dim, diffuse "nebulae" with spiral patterns
- Spiral structures catalogued mid-1800s by Lord Rosse (Ireland)


Rosse's M51 sketch


"Leviathan"
1.8 m telescope

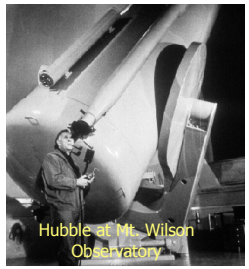
Those weird Spiral Nebulae?

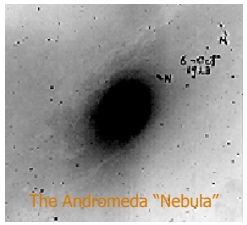
- Dim, diffuse, "interstellar" nebulae with spiral structure were seen in the 17th century.
- Some disagreement on what they were.
  - Kant: Our galaxy is a spiral "island universe" and the other spiral nebulae are the same and far away
  - Herschel and others: Milky Way is all there is in the Universe, and the spiral nebulae are nearby. More prevalent idea.



Edwin Hubble

- Finally solved, as it often is in astronomy, with a BIGGER telescope!
  - The old 100 inch trick!
- In 1923, Hubble resolved M31, the Andromeda "Nebula", into stars
- If these stars were like the stars in our Galaxy, then M31 must be far away!
- Estimated the distance to M31 to be 1 million lightyears (modern estimate is 2.54 Mlyrs)
- Andromeda is an "island universe" like our own Galaxy.

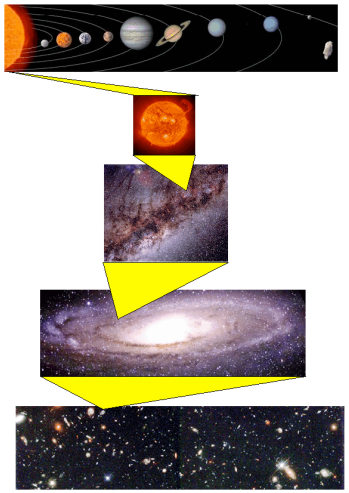




One of

We are:

- 1 planet out of ~~8~~ 9 in our solar system.
- 1 stellar system of 100 billion stars in our Milky Way
- 1 galaxy of the 100 billion galaxies in the observable Universe.



Galaxies – Fundamental "Ecosystems" of the Universe

- Galaxies "fill" universe.
- Typical separation **~ 3.2 million light years!**
- Most distance we can see are nearly 13 billion light years away
- Galaxies are huge masses of stars
- Range in size from large (MW-like) to small "Dwarf"
  - 1 billion to 500's billions of stars