

Our Milky Way Galaxy

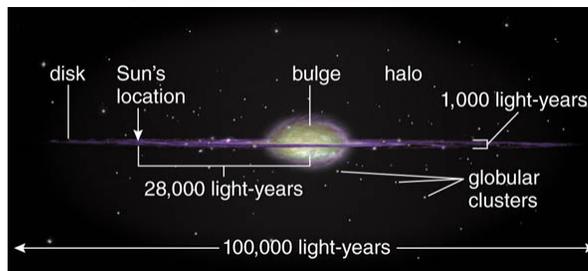
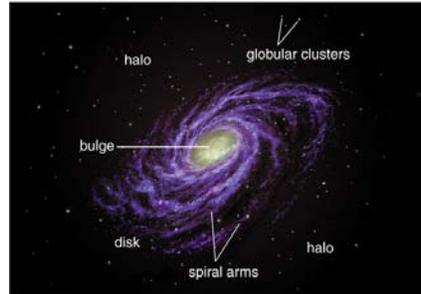
- What is our Milky Way Galaxy made of?
- Stars and gas orbit the galaxy.
- Dark, unseen, matter makes up most of the mass.



- Test 3 (New date)
 - Thurs, 9 April
 - One cheat sheet
 - Study guide & practice test
 - Link on syllabus
 - Add Jovian planets
 - Ignore neutron stars & black holes
 - Class of 3/26 (history of low and high-mass stars) is included. Today's class is not included.
- Missouri Club (Show me)
 - Tonight, 7:15-8:15pm
 - room 1420
- Observatory open house
 - Fri & Sat, 9:00-11:00pm.
 - MSU Observatory (south of Ag Pavilion)
 - Weather permitting.

Parts of the Milky Way

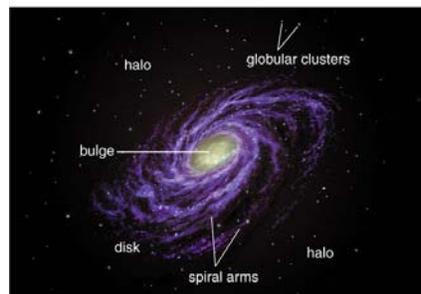
- Disk
 - Stars, gas, and dust
 - Young & old stars
 - Motion is circular
- Bulge
 - Stars are dense
 - Motion is elliptical in all directions
- Halo
 - Stars are sparse; dark matter
 - No young stars
 - Spherical in shape
 - Motion is elliptical in all directions
- Globular clusters



You are the sun. The students in the room are O stars. The center of the Milky Way is drawn on the board.

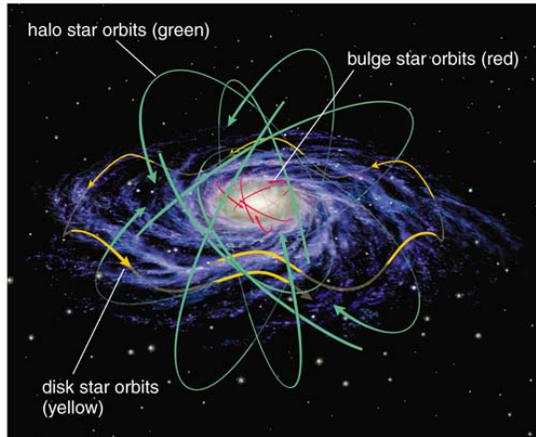
1. Where is the disk?
 - a. All around, including up & down
 - b. Above the ceiling
 - c. Toward the front of the room
 - d. Within a few meters of the floor
2. Where is the halo?
3. Where is the dust & gas?
4. Where do you see the most stars?

Parts of the Milky Way



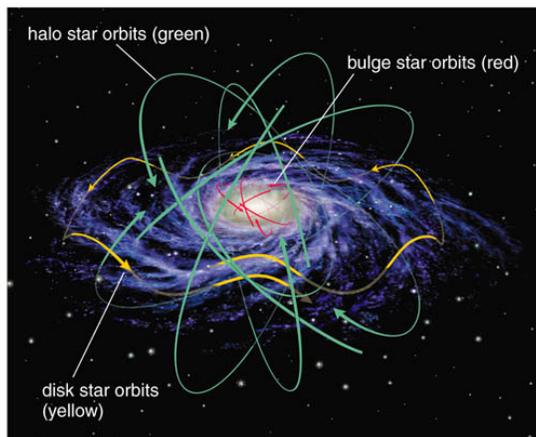
- Disk stars move in a circle around the center of the Milky Way. Orbits dip above and below the plane of the disk.
 - Halo and bulge stars move in long, skinny orbits in all directions.
 - Why do some stars move in a circle and others move in a skinny orbit?
5. Why does the earth move in a circle today?
- a. Planets are heavenly objects.
 - b. It moved in a circle yesterday.

Orbits of stars



- Why do some stars move in a circle and others move in a skinny orbit?
6. Why does the earth move in a circle today?
- a. Planets are heavenly objects.
 - b. It moved in a circle yesterday.
7. Why does the earth move in a circle?
- a. The material from which the earth formed moved in a circle.
- Orbit determined at star's birth.
 - Gas that formed disk stars was orbiting MW in a circle
 - 1. Gas that formed halo stars was streaming toward MW. 2. Halo stars were in a little galaxy that got caught by MW.

Orbits of stars



Galaxies fill space around us

- Earth
 - 6Mm in radius. 1/50 light-sec
- Solar system
 - Earth is 1 AU from sun. 1/63,000 light-year, 9 light-min (20,000x)
- Nearest star
 - Distance to Proxima Centauri is 4 ly (200,000x)
- Milky Way galaxy
 - Distance to center is 30 kly (10,000x)
- Nearest big galaxy
 - Distance to Andromeda is 2 Mly (100x)
- Farthest galaxy seen
 - Distance is 10 Bly (5,000x)



Loneliest object

- Earth
 - 6Mm in radius. 1/50 light-sec
 - Solar system
 - Earth is 1 AU from sun. 1/63,000 light-year, 500 ls (20,000x)
 - Nearest star
 - Distance to Proxima Centauri is 4 ly (200,000x)
 - Milky Way galaxy
 - Distance to center is 30 kly (10,000x)
 - Nearest big galaxy
 - Distance to Andromeda is 2 Mly (100x)
 - Farthest galaxy seen
 - Distance is 10 Bly (5,000x)
- Planets are 10,000 earth-radii away from earth. Analogy: you are 10,000 persons (12mi) away from the next person.
1. Which is the loneliest kind of object?
 - a. Earth to next planet
 - b. Solar system to next star
 - c. Star-star to center of MW
 - d. MW to next galaxy

Loneliest object

- Earth
 - 6Mm in radius. 1/50 light-sec
 - Solar system
 - Earth is 1 AU from sun. 1/63,000 light-year, 500 ls (20,000x)
 - Nearest star
 - Distance to Proxima Centauri is 4 ly (200,000x)
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 - Distance to center is 30 kly (10,000x)
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 - Distance to Andromeda is 2 Mly (100x)
 - Farthest galaxy seen
 - Distance is 10 Bly (5,000x)
- Planets are 10,000 earth-radii away from earth. Analogy: you are 10,000 persons (12mi) away from the next person.
 1. Which is the loneliest kind of object?
 - a. Earth to next planet (12mi)
 - b. Solar system to next star (250mi)
 - c. Star-star to center of MW (12mi)
 - d. MW to next galaxy (200m)

Weighing a Galaxy

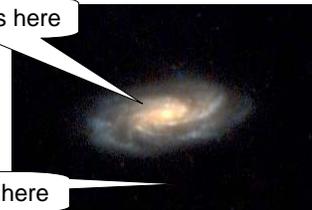
- What is the mass of a galaxy?
 - Answer before 1974: Mass is that of stars & gas
 - Actual answer: Most mass is not that of stars & gas
 - Most mass is dark
 - Dark mass is less concentrated.
- How to measure



Fritz Zwicky 1898-1974
www.astrosurf.org/lombry/images/zwickyf.jpg



Vera Rubin 1928-
cwp.library.ucla.edu/images/rubin.1.jpg



NGC 3672
www.astro.princeton.edu/~frei/Gcat_html/Catalog/CJpeg/n3672.jpg

Weighing Eros

- Near Earth Rendezvous (NEAR) orbited the asteroid Eros (and landed).
<http://near.jhuapl.edu>
 - Eros
 - 20mi long, 8mi wide (size of Lansing)
 - Gravity is 1000 times weaker
 - You can leap 1000 times farther
 - $\frac{1}{2}v^2 = g h$
 - Speed limit is 20mph
 - $v^2 = g R$
 - On Earth, a ball dropped 1m takes 0.45s. How long would that take on Eros?
 - $\frac{1}{2}v^2 = g h$; $v = g t$; $t = (2h/g)^{1/2}$
 - $t = 0.45s (1000)^{1/2} = 14s$
1. How can you measure the mass of Eros with the satellite (without landing)?



Weighing the Sun

- To find mass of sun, measure period T & size R of a planet's orbit.
 - Kepler's 3rd Law
 $GM = 4\pi^2 R^3 / T^2$
 - $M = R^3 / T^2$ for R in AU, T in years, and M in solar masses.
- 2. Under influence of the gravity of the sun, a planet moves a given distance. If the time is short, the mass of the sun is
 - A. greater.
 - B. less.

| Mass | Test object | Motion | Behavior if more massive |
|--------|-------------|----------|--------------------------|
| Sun | Earth | An orbit | |
| Eros | | | |
| Earth | A ball | Drops 1m | Time is shorter |
| Galaxy | | | |