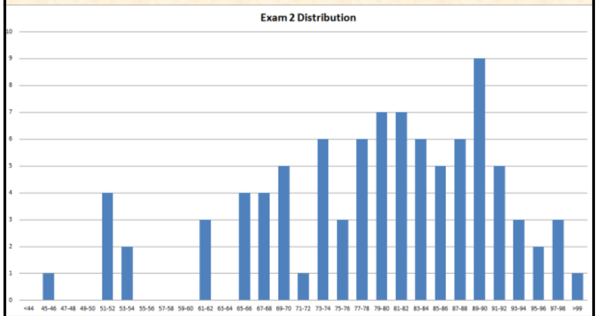
ASTR 1020: Stars & Galaxies

October 28, 2013

- Reading: Chapter 19, sections 19.2-19.4.
- *Mastering Astronomy* Homework on The Milky Way is due Nov. 1.

Exam 2 Grade Distribution



Average = 79%, Median = 81%, Standard Dev. = 12%
Max = 99%, Min = 45%

Astronomy Picture of the Day

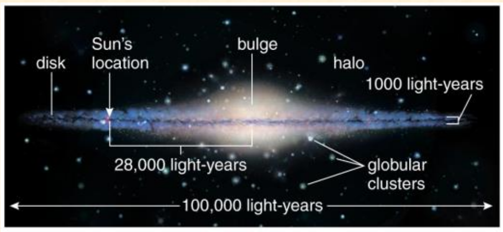
For reasons unknown, NGC 6357 is forming some of the most massive stars ever discovered. One such massive star, near the center of NGC 6357, is framed above carving out its own interstellar castle with its energetic light from surrounding gas and dust.

Today: Stellar Motions & Dark Matter in the Milky Way

Disk: includes spiral arms

Young, new star formation

Bulge & Halo: older stars, globular clusters



Reading Clicker Question: Where are most star-forming regions in the Milky Way?

A. the central bulge
B. the halo
C. the spiral arms
D. the regions between the spiral arms
E. Star formation happens at roughly the same rate in all regions of the Milky Way.

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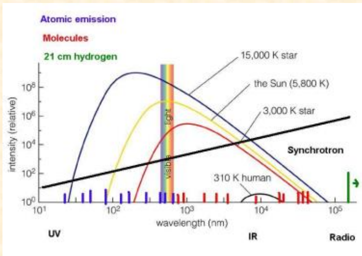
Looking Across the Spectrum

- Review of ways to make light:

- Thermal (IR-> UV)
- Synchrotron (all wavelengths)
- Emission lines:
  - atoms → visible/UV
  - molecules → IR
  - Hydrogen→ 21-cm = radio

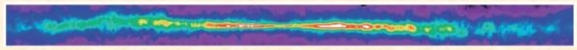


The Milky Way Across the Spectrum

REVIEW FIGURE 19.12 in textbook, note symbols for telescope types

Radio

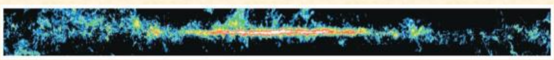
- 21 cm emission emitted by atomic hydrogen show where gas has cooled and settled into disk (below).



- Synchrotron emission from supernova remnants, neutron stars, black holes etc.

Radio (millimeter wavelength) & Far IR

- Emission from molecules (CO)



Infrared (100 microns)

- Long-wavelength infrared emission shows where young stars are heating dust grains at a few hundred degrees K

Near infrared

- Cool stars

(low-mass main sequence stars, red giants)

Visible and UV light:

- Sun-like and hotter stars
- Hot gas
- Dust absorbs light!!!!!!!!

Another Galaxy in Visible Light

- Star formation, molecular clouds, young blue stars and warm/hot gas and dust found in spiral arms

The Whirlpool Galaxy, M51

- X-rays: million degree gas, synchrotron emission

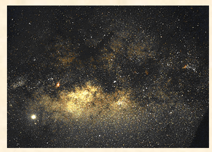
- Hot gas bubbles
- X-ray binaries (synchrotron emission)
- Some absorption by gas/dust

Clicker Question: We want to map out the structures of very cold gas within the dusty disk of the Milky Way. What wavelength should we be using, and why?

a) radio
b) visible light
c) X-rays

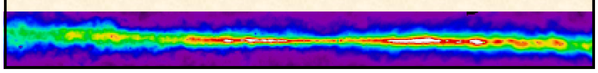
(A) Radio!

- Dust obscures our vision of much of the galaxy in visible and UV light.



- X-rays only highlight the hottest and weirdest places

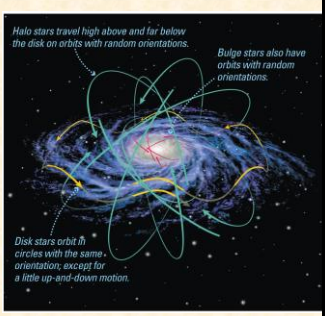
- 21 cm radio waves map normal hydrogen gas, these pass through dust unaffected



Solar Circle

- Take about 230 million years to get around

- Sun has been around about 20 times



Mass in the Galaxy

- Star orbits are in response to gravity.

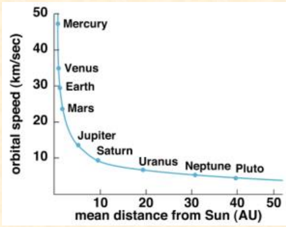
- Measure star speeds via Doppler shift.

- Faster orbits → more mass.

- Mass of Milky Way =$1.0 \times 10^{11} M_{\text{Sun}}$
That is 1.9×10^{41}kg*!*

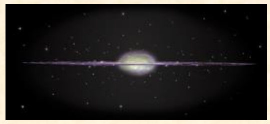
Measuring Mass: Rotation curve for gravity

- Example: Solar System
- Almost ALL the mass is in the center (Sun)
- Gravity weaker farther out
- Rotation curve falls



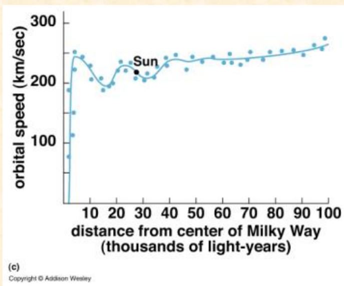
Expectation for the Milky Way

- There are a lot of stars in the center but also some outside
- Rotation curve should fall but more slowly than solar system



Reality for the Milky Way

- Rotation curve is flat or even rising!
- Most of the mass of the galaxy is outside the solar circle!
- But few stars, little gas there…
- DARK MATTER?!



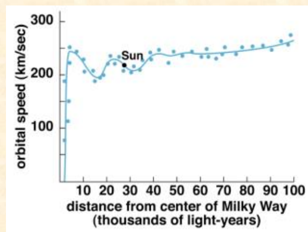
Mass = R x V^2 / G

R = radius; V = orbital velocity

Very little gas or stars at large radii → not much to measure

Still don't know the extent of the dark matter

Possibly outweigh stars by factor of 10!



- Stars and gas are embedded in a much larger Dark Matter Halo??
- Don't know what dark matter is yet….