Problem Sets 6 and 7 now posted on website
(PS 6 due next Thursday)

Last Exam will be given on April 24

Results of this exam
  Average 66.8
  Standard Deviation 14.5

Website
http://casa.colorado.edu/~wcash/APS1120/APS1120.html
The Milky Way
Stars Beyond Counting
100 Billion Stars
Orbital Period

\[ P = 2\pi \sqrt{\frac{R^3}{GM}} = 6.28 \times \sqrt{\frac{(10000 \times 3 \times 10^{16})^3}{6.7 \times 10^{-11} \times 10^{12} \times 2 \times 10^{30}}} = 3 \times 10^{15} \text{ s} = 10^8 \text{ years} \]

Takes the Sun 200 million years to orbit Milky Way.

Sun is 4600 million years old.

The Sun is 23 Galactic Years Old.
A Spiral Galaxy Like Milky Way
Milky Way – Edge-On
The Milky Way
Formation of Milky Way

• Analogous to formation of the Sun
• Start with big blob of gas
• Let it collapse

Disk Stability Again
Globular Clusters

Gas has friction and collapses to disk.

Stars have huge momentum with small cross section.

When a star forms it remains frozen in its initial orbit forever.

Little knots of high density are first to form into stars.

These are the globular clusters.

They each contain a million stars. There are about 100 orbiting the Milky Way.
The Globular Cluster – M80
Formation of MW

Second, stars in bulge are formed. Cloud is flattened but not totally.

Third, all the remaining gas falls into disk. The galactic plane.

Fourth, stuff that loses orbital velocity falls to center. Forms “Nucleus”
Infrared
Galactic Center
Central Parsec
Black Hole in Milky Way

Dead Center in the middle of the Milky Way.

2.7 Million Solar Masses!
Rotation Curves

- Left graph: Orbital speed vs. mean distance from Sun (AU) for planets including Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto.
- Right graph: Orbital speed vs. distance from center of Milky Way (thousands of light-years) showing a dip near the Sun.
- Bottom graph: Orbital speed vs. distance from center of a merry-go-round (m), showing a linear relationship.
Winding Problem

In under a billion years spirals would be wiped out.
Spiral Density Waves

Stars linger within the spiral arms, enhancing the density of the spiral arms and increasing their gravitational pull.

Gas clouds, following the same orbits as stars, collide, compress, and collapse where the orbits come close together, leading to the formation of new stars in the spiral arms.
Dust lane arises on inner edge of spiral arm where gas clouds crowd together.

Young blue stars are found on outer edge of spiral arm.

Ionization nebulae arise where newly forming blue stars are ionizing gas clouds.
Dark Matter

- Rotation Curves
- Speed of Rotation
- Stability

- Only 10% of matter in Milky Way is in stars, gas and other normal matter

- Same as rest of universe
- Don’t know what dark matter really is.