Matter, Dark Matter, and Dark Energy

Pre-Lecture Questions

No Problem Set!

Lecture Outline

1. Ordinary Matter
2. Dark Matter
3. Dark Energy and the Expansion of the Universe

Pre-Class Summary:

Ordinary Matter is the stuff we are made of - atoms.

Dark Matter is the name of the problem associated with the orbital motion of stars within a galaxy.

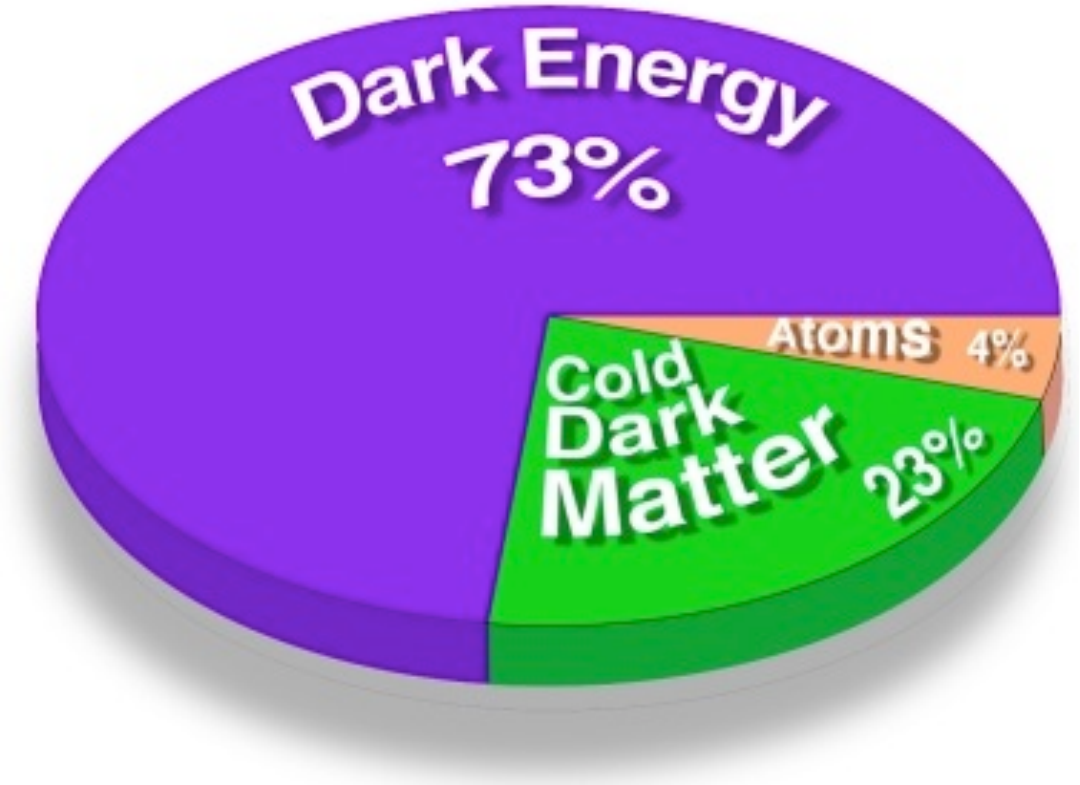
Evidence is from:

- The orbital motion of stars with galaxies
- Gravitational Lensing

Dark Energy is the name of the problem associated with the accelerating expansion of our universe.

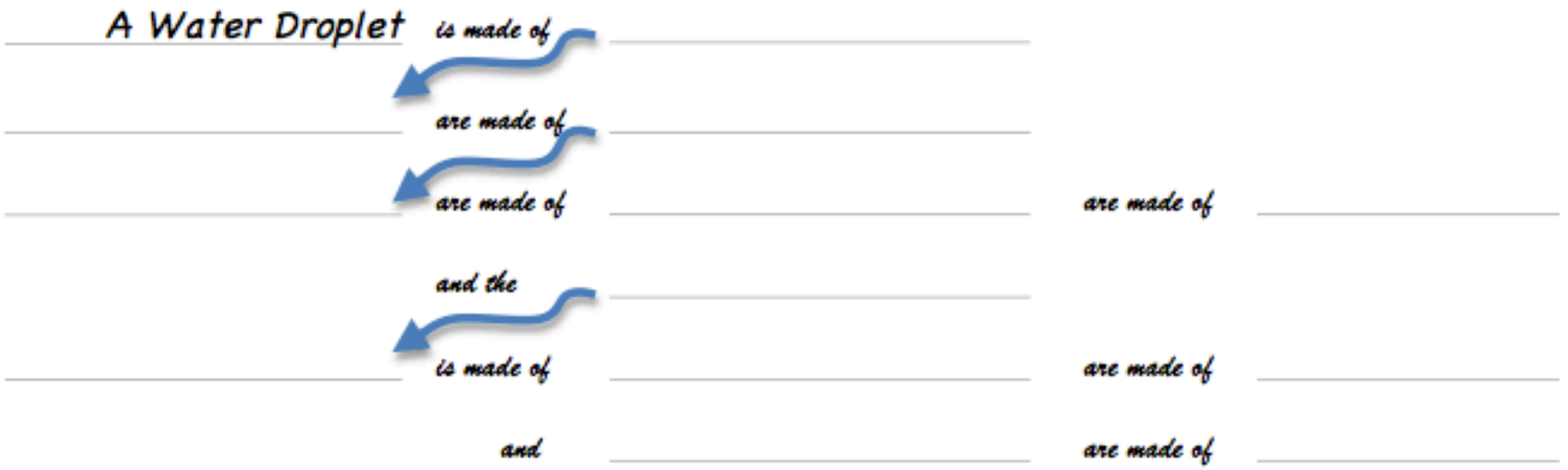
Evidence is from:

- The velocities of the galaxies throughout the universe.

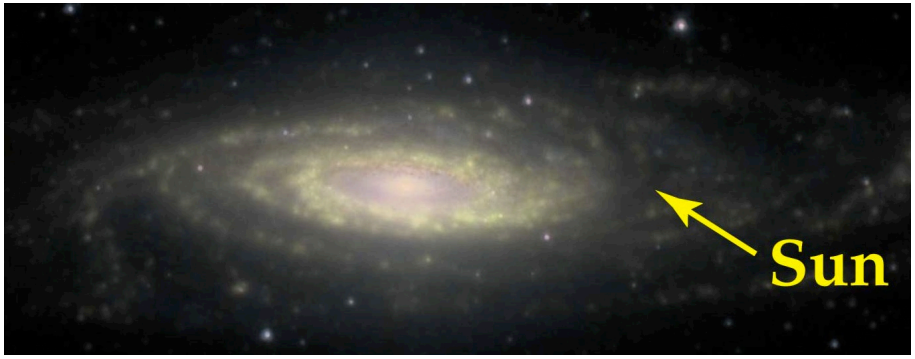

Dark Energy
73%
Atoms 4%
Cold
Dark
Matter
23%

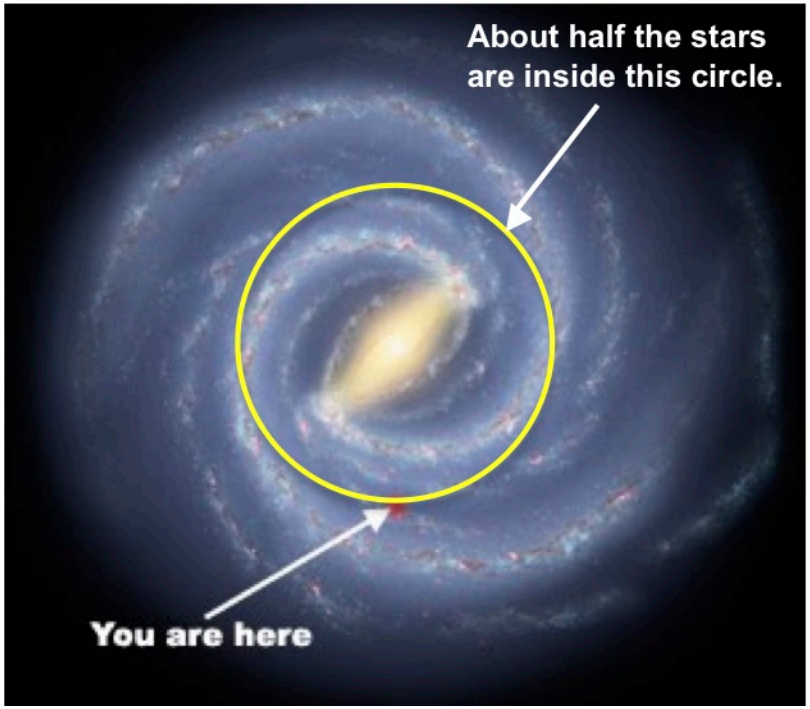
What Are You Made Of?

You are made mostly of water, but what is water (and for that "matter" everything else) made of. Fill in the table below. The answers are below, but not in the correct order. Once you write the answer on a line, rewrite it as indicated by the blue arrow to begin the next line.



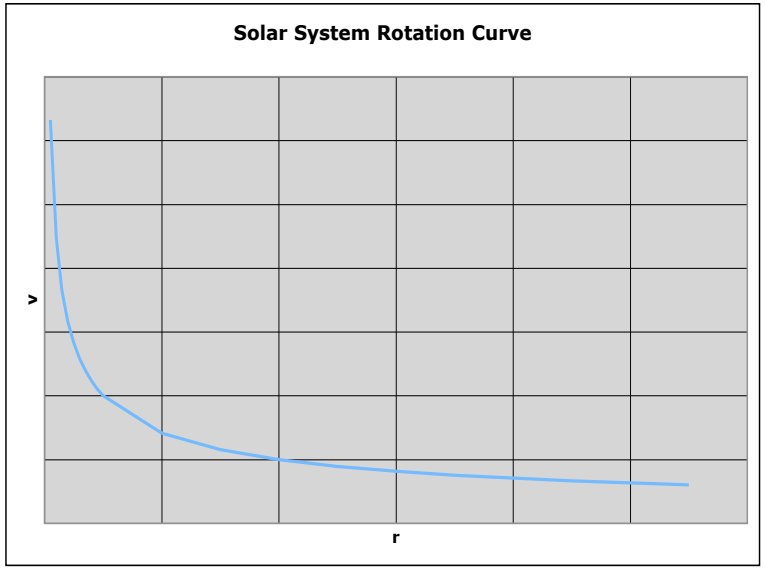
Answers: Atoms, Neutrons, Quarks, Nucleus, Molecules, Nothing, Protons, Electrons

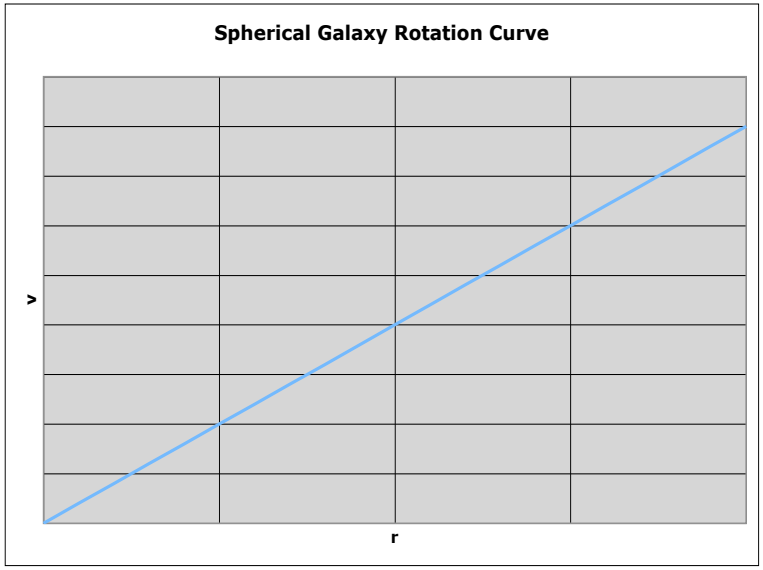

Sun


About half the stars
are inside this circle.
You are here

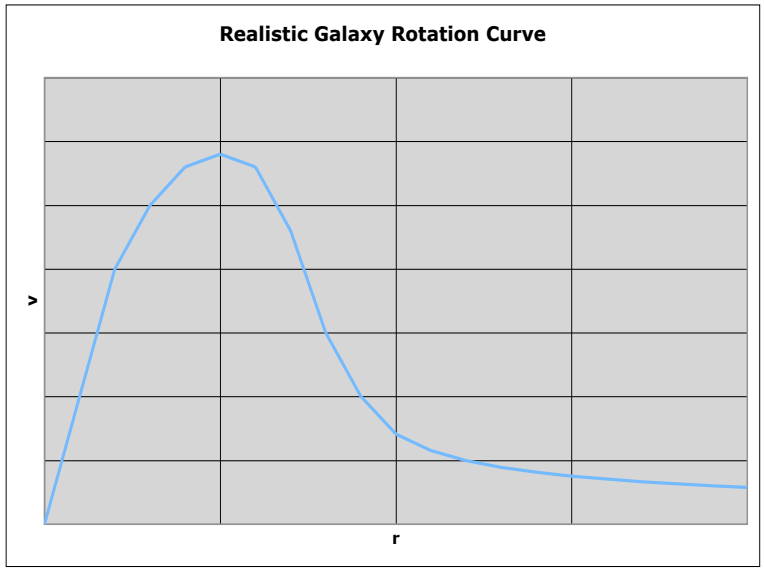
Example 1: We are 27,200 light-years from the center of the Milky Way that contains about 100 billion stars. Our best estimates indicate the sun is an average star and about half the stars in the galaxy are closer to the center than the sun. Find the orbital speed of the sun.

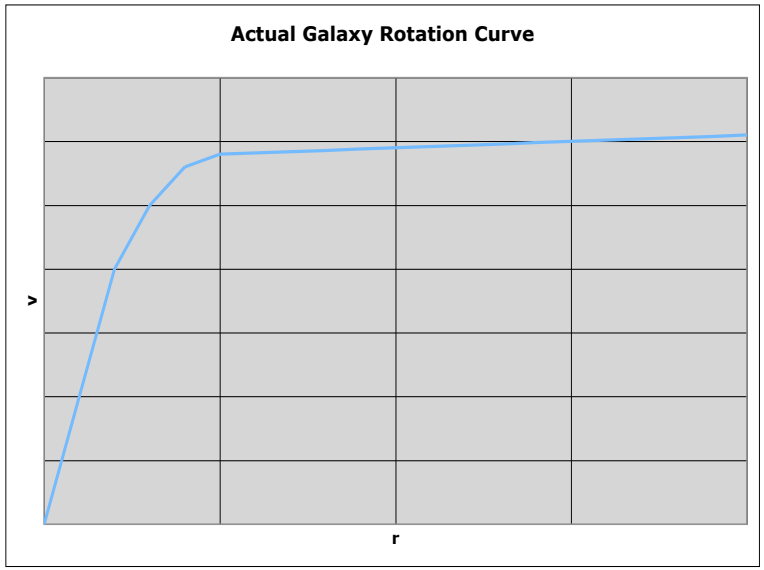
Rotation Curves



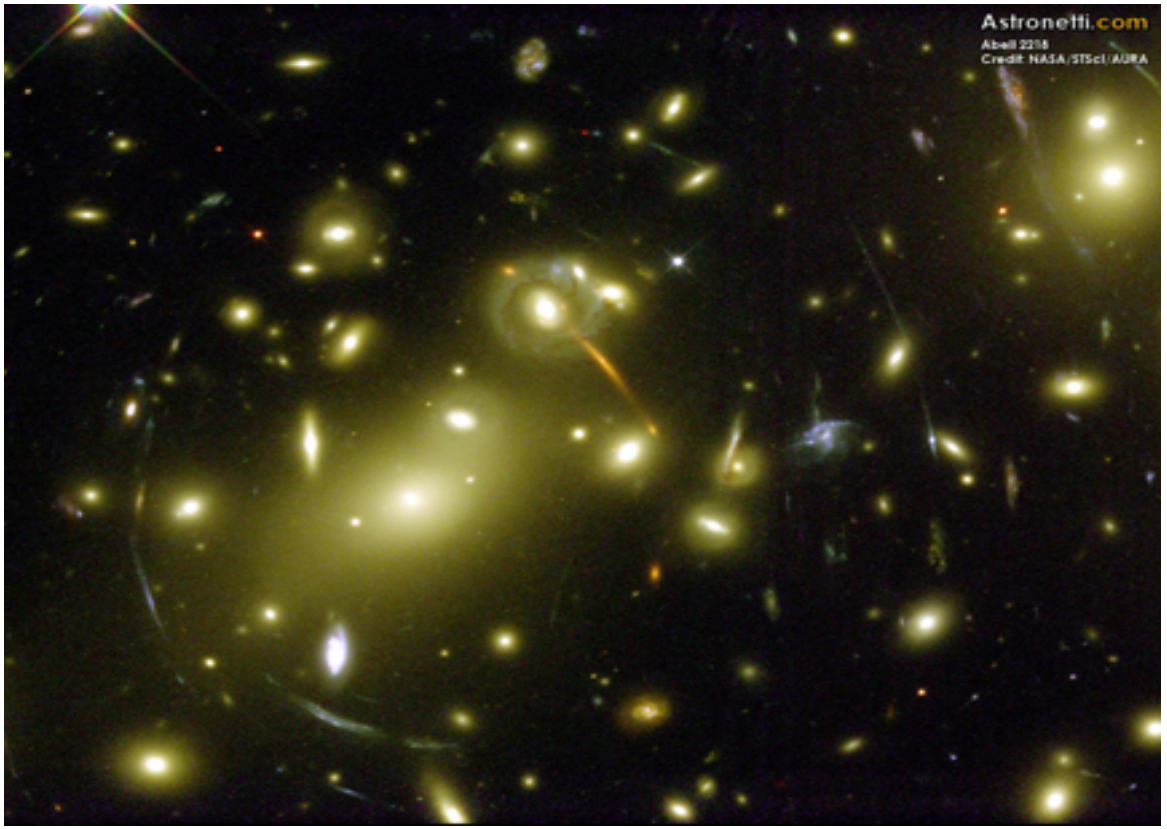


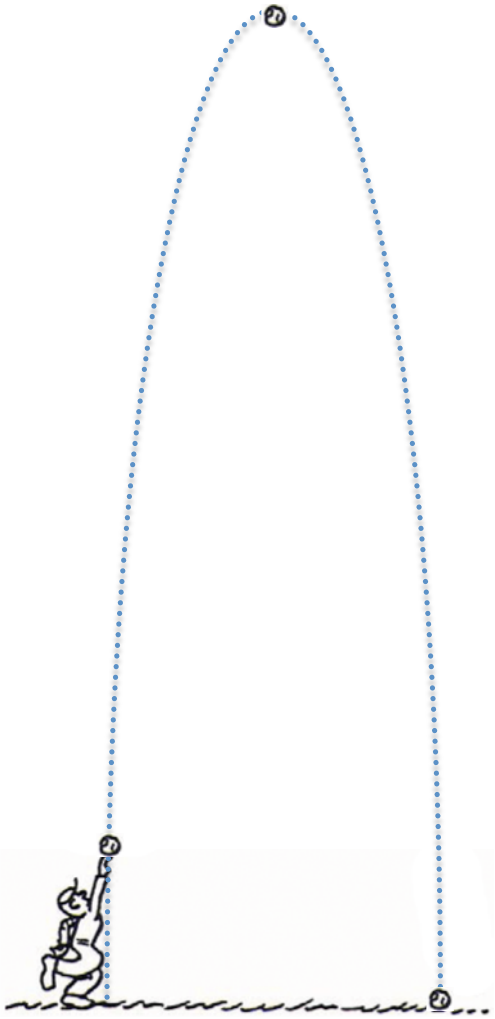
Rotation Curves





Additional Evidence for Dark Matter – Gravitational Lensing



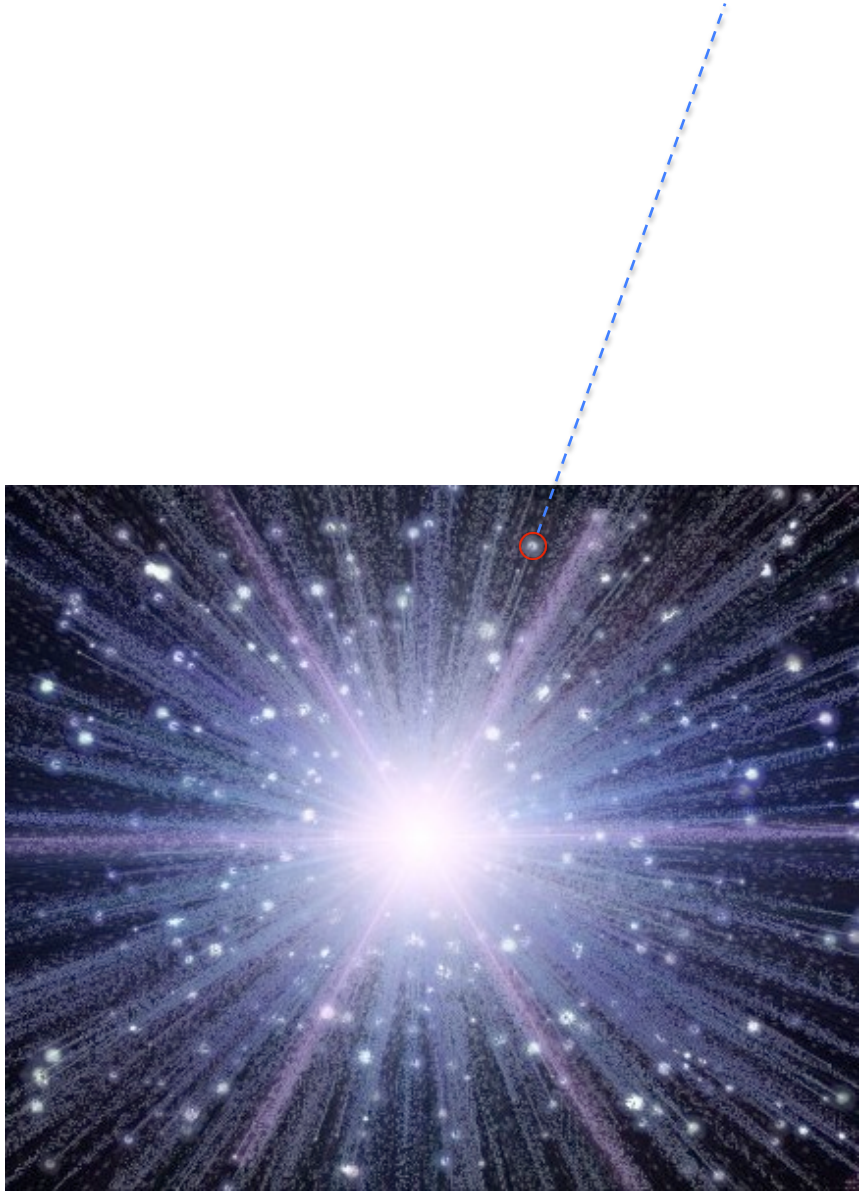


A baseball player throws a ball upward along the trajectory shown.

1.Draw three additional images of the ball on the way up. The images should be equally spaced in time.
2.Is the ball speeding up, slowing down or moving at a constant speed?
3.What is causing the ball to behave this way?
4.How does your sketch reflect your answer to part 2?

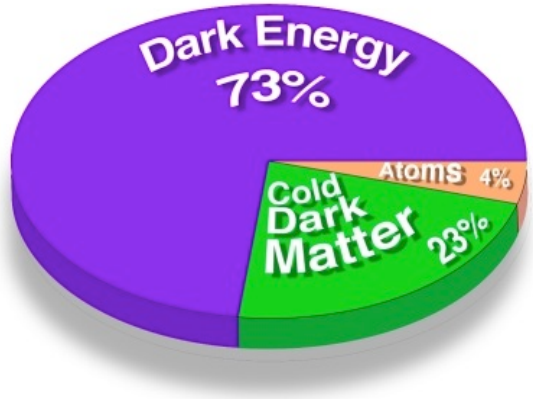
Here is an artist's conception of the Big Bang. The trajectory of the galaxy is circled in red is shown.

1. Draw three additional images of the galaxy on the way out. The images should be equally spaced in time.
2. Is the galaxy speeding up, slowing down or moving at a constant speed?
3. What is causing the galaxy to behave this way?
4. How does your sketch reflect your answer to part 2?



Example 2: The most distant galaxies are about thirteen billion light-years away. Assume such a galaxy has the same mass as the Milky Way (100 billion stars) and that the universe contains about 10^{23} stars. On average each star has the mass of the sun. Estimate the minimum size of the mysterious force causing a distant galaxy to accelerate.

Lecture 40 - Summary



Ordinary Matter is the stuff we are made of - atoms.

Dark Matter is the name of the problem associated with the orbital motion of stars within a galaxy.

Evidence is from:

- The orbital motion of stars with galaxies
- Gravitational Lensing

Dark Matter is the name associated with the accelerating expansion of our universe.