ASTR 1020: Stars & Galaxies

April 9, 2008

- Reading: Chapter 22, sections 22.3.
- *MasteringAstronomy* Homework on Dark Matter is due April 14th.
- Meet at Planetarium for next class!
- Last midterm Exam next week – Wednesday, April 16th: Chapters 19.3-22.3.

Today

- Gravitational Lenses
- The Search for Dark Matter
- Large Scale Structures in the Universe

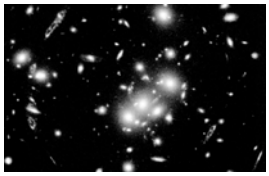
Clicker Question: gravitational lens

If you measure the redshifts of the red and blue objects, you'll find:

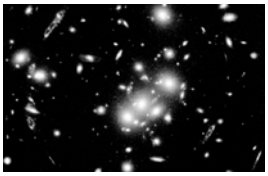
A) The red galaxies have similar redshifts, all higher than the blue galaxies

B) The blue galaxies have the same redshift, which is higher than the red galaxies

C) Red and blue galaxies have similar redshifts

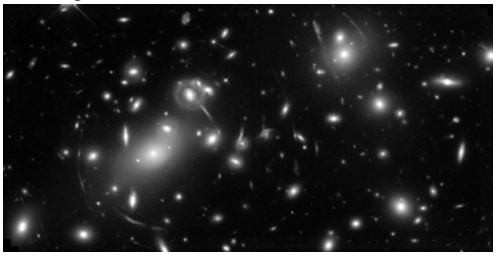


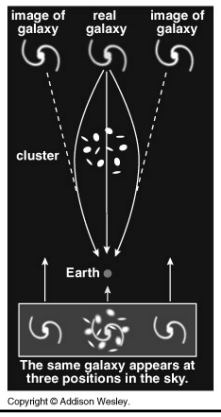
- **B)** The blue images are a single BACKGROUND galaxy being lensed by the foreground cluster (red galaxies)
- The blue galaxy is farther from us and thus will have a higher redshift



Gravitational Lenses

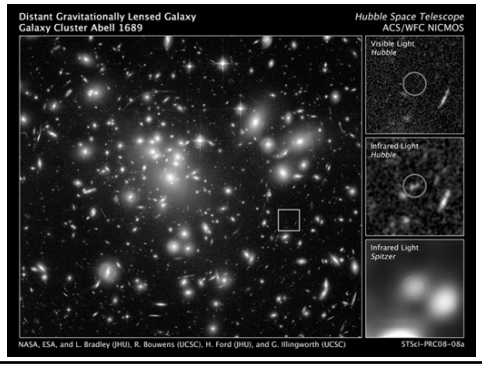
- Dark matter warps space → acts like a lens and distorts and magnifies the view of more distant galaxies

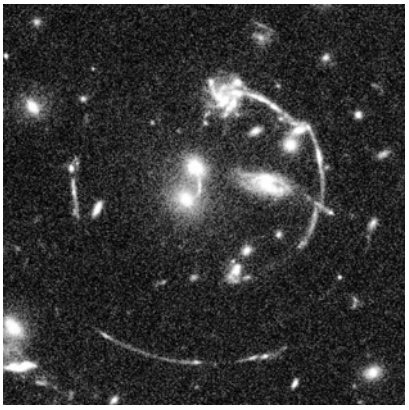




Astronomy in the News

Larissa Rhodes





"The Beast:'

4 or 5 different galaxies!

Red arc at the bottom: z=4.8

How much Dark Matter?

- All cluster methods generally agree
- About 10 times as much dark matter as "normal" matter overall in the universe
- Note that our solar system is NOT typical- much more light matter than dark matter here! Expected mass of DM inside the Earth's orbit is an immeasurably small fraction of the Sun's mass
- Mass-to-Light ratio is high in the Milky Way halo but low in the solar system.

Normal Matter versus Dark Matter

- Normal matter: based on protons and neutrons = "baryons"
- Normal matter = Baryonic Matter

Is Dark matter baryonic or something different and new?

What is dark matter?

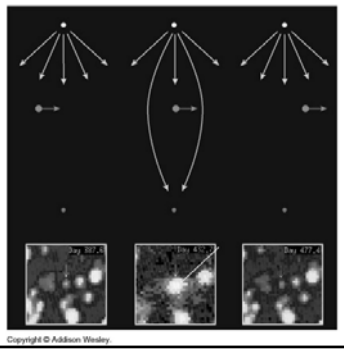
Two flavors for Dark Matter:

1) MACHOs

- Massive Compact Halo Objects
- Stuff we've studied already: very faint, things; baryonic matter
- Brown dwarfs, black holes, black dwarfs etc.
- May be floating through the galaxy halo unnoticed

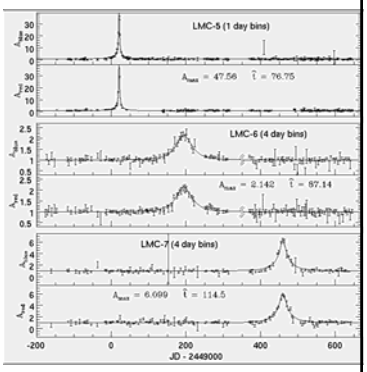
MACHO Searches

- Use gravitational lensing:
- When a MACHO floats in front of a star, star suddenly brightens
- Focusing effect of compact massive object



Results:

- MACHOs are detected
- But not enough to explain all dark matter



2) WIMPs

- Weakly Interacting Massive Particles:
- Non-baryonic → subatomic particle
- Neutrinos? Probably not…. They move too fast and can't be collected into stable galaxy halos

Other unknown particles???
Slower particles: "Cold Dark Matter"

Clicker Question: Based on observational evidence, is it possible that dark matter doesn't really exist?

a) No, the evidence is too strong
b) Yes, but only if there is something wrong with our understanding of how gravity works on large scales
c) Yes, but only if all the observations are in error

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Dark Matter & the Formation of Structure

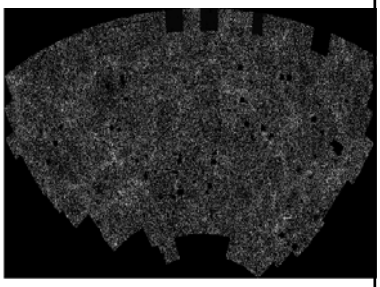
In the beginning:

Very small "ripples" in density

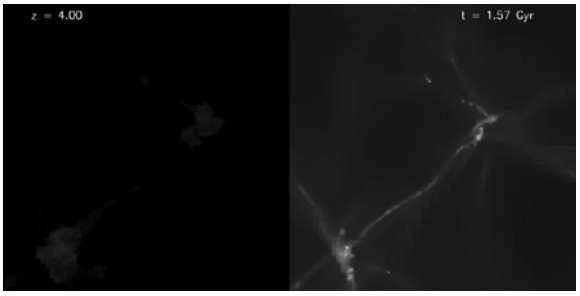
Gravity pulls together dark matter in slightly denser regions to form dark halos

"Light" matter radiates energy and sinks to the middle to form galaxies

- Gravity pulls galaxies and dark matter into large structures:
- Clusters, superclusters
- Walls, filaments
- Voids



Evolution of Galaxy Clusters



Real data versus computer simulations