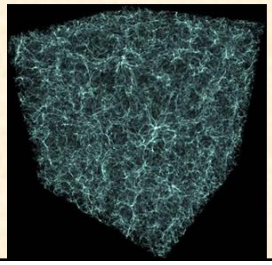
ASTR 1020: Stars & Galaxies

November 15, 2013

- Reading for Monday: Chapter 23, section 23.1-23.3.
- *MasteringAstronomy* homework on Galaxy Evolution is due tonight at midnight.
- Exam 3 is on Wednesday, Nov. 20.



Astronomy Picture of the Day

The dark Horsehead Nebula and the glowing Orion Nebula are contrasting cosmic vistas. Adrift 1,500 light-years away in one of the night sky's most recognizable constellations, they appear in opposite corners of the above stunning mosaic.

Today

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

Clicker Reading 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.

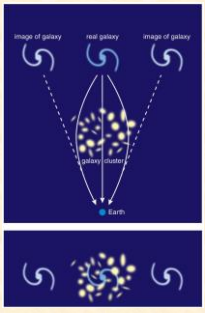
B) The blue galaxies all have the same redshift, which is higher than the red galaxies.

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

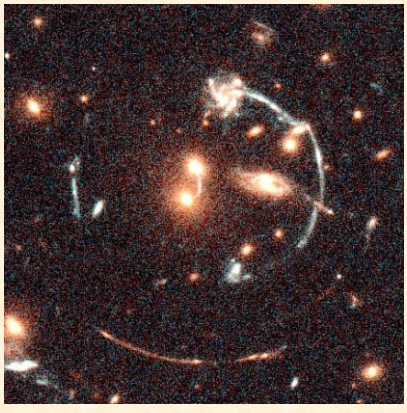
Gravitational Lenses

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



Gravitational lensing, the bending of light rays by gravity, can also tell us a cluster's mass.

Gravitational Lens Simulation

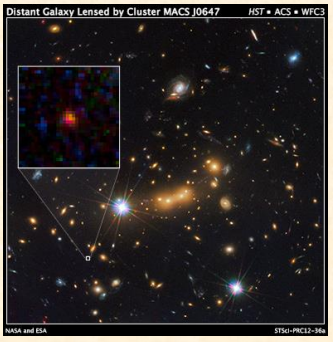


"The Beast"

4 or 5 different galaxies!

Red arc at the bottom: z=4.8

A Very Distant Galaxy behind a Cluster



- Lensed, red galaxy with estimated z=11!
- At this redshift, its age is only 420 million years or only 3% of the age of the Universe.

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.

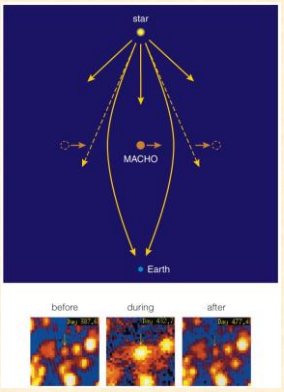
Normal Matter versus Dark Matter

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

Is Dark matter baryonic or something different and new?

Two Basic Options for Dark Matter

- Ordinary Dark Matter (MACHOS)
  - Massive Compact Halo Objects: dead or failed stars in halos of galaxies
- Extraordinary Dark Matter (WIMPS)
  - Weakly Interacting Massive Particles: mysterious neutrino-like particles



MACHOs occasionally make other stars appear brighter through lensing…

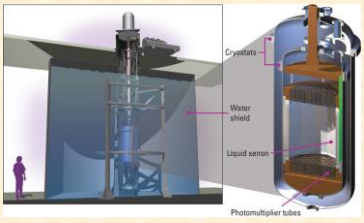
… but there are not enough lensing events to explain all the dark matter.

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"

Recent Search for WIMPs



Large Underground Xenon detector at Underground Research Facility in Lead, SD failed to find "light weight" WIMPs

Axion Dark Matter Experiment at University of Washington

Why Believe in WIMPs?

- There's not enough ordinary matter.
- WIMPs could be left over from Big Bang.
- Models involving WIMPs explain how galaxy formation works.

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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So, our options on Dark Matter are:

1. Dark matter really exists, and we are observing the effects of its gravitational attraction.

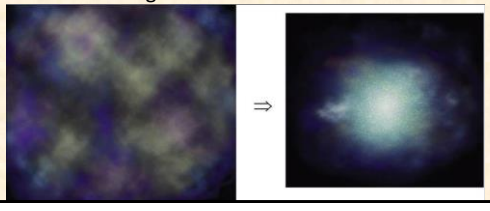
2. Something is wrong with our understanding of gravity, causing us to mistakenly infer the existence of dark matter.

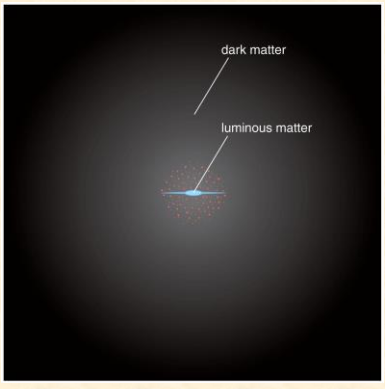
Because gravity is so well tested, most astronomers prefer option #1.

Dark Matter & the Formation of Structure

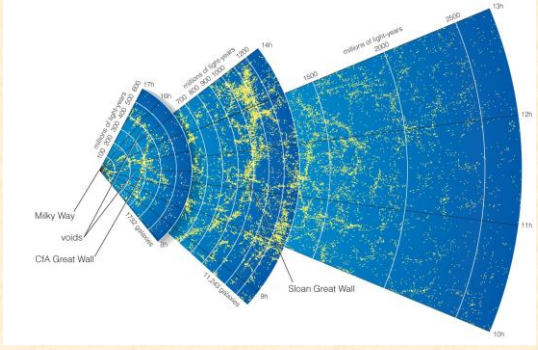
In the beginning:

- 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

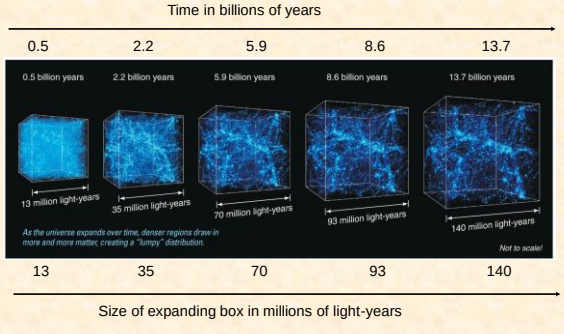




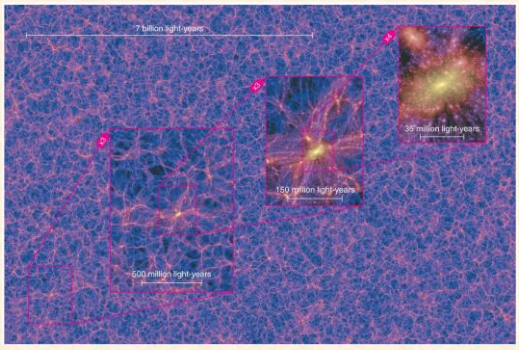
WIMPs can't collapse to the center because they don't radiate away their orbital energy.



Maps of galaxy positions reveal extremely large structures: ***superclusters*** and ***voids***.



Models show that gravity from dark matter pulls mass into denser regions—the universe grows lumpier with time.



Structures in galaxy maps look very similar to the ones found in models in which dark matter is WIMPs.